



BOOK OF ABSTRACTS

STUDYING OLD MASTER PAINTINGS -
TECHNOLOGY AND PRACTICE

THE NATIONAL GALLERY TECHNICAL BULLETIN
30TH ANNIVERSARY CONFERENCE

16-18 September 2009, Sainsbury Wing Theatre, National Gallery, London

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PRESENTATIONS

The *Paliotto* by Guido da Siena from the Pinacoteca Nazionale of Siena

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The *Paliotto* (91 x 187 cm), now in the Pinacoteca Nazionale of Siena, was probably painted by Guido da Siena, in the 1270s. Its attribution and its probable date of execution make it the earliest example of medieval painting on a textile support in Tuscany. This precious painting has never been the object of a detailed study, and has always been considered mysterious, due to the absence of information on its history, technique and past conservation.

This paper will deal with the technical, historical and scientific results of the examination of this unique painting and will underline the importance of studies and investigation in planning a complex conservation project. Despite the lack of any possible comparison with other paintings of the same period, the understanding of the original materials and technique is based on scientific analyses to be related to documentary sources. Relationships to recipes in treatises and documentary sources and to the *tüchlein* technique are investigated.

The artistic technique appears to be similar to that used in panel paintings but displays many modifications which could have been required by the function of the *Paliotto* itself (an easily portable painting). The original linen support is extremely thin and, at first, might be interpreted as silk. The particular preparatory layer, basically glue applied in thin layers, is used to achieve a smooth and elastic surface. The mordant gold leaf in the background aimed to achieve the aesthetic effect of gold on panel paintings. The paint film is very thin and the canvas texture is clearly visible on the surface. The painting was originally enriched by mordant silver leaf decorations which gave the effect of an embroidered textile.

Painting on parchment and panels: An exploration of Pacino di Bonaguida's technique

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Pacino di Bonaguida, a panel painter and manuscript illuminator active in Florence, was a prolific artist thought to have produced the majority of illuminated manuscript commissions in Florence during the first half of the fourteenth century. He was also an accomplished panel painter, producing many altarpieces and other devotional works. The body of work attributed to Pacino is expansive, suggesting a large workshop; visual comparisons and technical analysis are essential for understanding his working methods. As part of an upcoming exhibition in 2012 (organized by the J. Paul Getty Museum) exploring Pacino and his workshop within the context of early Florentine painting and illumination, technical analysis of several works in both media by the artist has recently been undertaken.

The Getty owns three leaves from the *Laudario* of Sant'Agnese, Pacino's most important manuscript commission. Two of the leaves are by Pacino and one is by his known collaborator, The Master of the Dominican Effigies. Analysis of these leaves, along with others from the same commission, provides insights into the working methods of the two artists as well as workshop practice.

Pacino's panel paintings often use compositions of multiple small-scale scenes, as is evidenced in the Getty Museum's Chiarito Tabernacle. Because this format reduces figure scale, visual comparisons between the larger panel paintings and the smaller illuminations are easily made and are a rich source for technical comparison. Certain passages of the Tabernacle appear to have undergone significant changes over time. However, because of their better state of preservation, Pacino's manuscript illuminations provide corroborative and valuable information about Pacino's palette and thus contribute to understanding the present appearance of the panel painting.

Analysis of both manuscripts and panel paintings has revealed some interesting aspects of Pacino's technique, allowing parallels and contrasts between the two media to be drawn. This paper will include preliminary results from scientific analyses of the Getty's works. Analysis of the pigments in the manuscript leaves was conducted using the non-invasive techniques of X-ray fluorescence (XRF) and Raman spectroscopy. For the panel painting,

additional analysis of the stratigraphy of paint layers was carried out through the examination of cross-section samples by optical and scanning electron microscopy. Imaging techniques, including infrared reflectography and multi-spectral imaging, were employed in the study of both the manuscript leaves and the panel painting in order to examine underdrawings and map pigment distributions.

This investigation constitutes the first stage of a larger study into the techniques of Pacino and his collaborators and workshop, which will include additional studies of manuscript illuminations and panel paintings from other institutions. By employing an interdisciplinary approach, combining scientific analysis with information from documentary sources and art historical perspective, this study will help to elucidate the relationship between panel painting and manuscript illumination.

Technical similarities between mural painting and panel painting in the works of Giovanni da Milano: The Rinuccini Chapel, Basilica of Santa Croce, Florence

Fabrizio Bandini, Alberto Felici, Cecilia Frosinini, Carlo Galliano Lalli, Mariarosa Lanfranchi, Paola Ilaria Mariotti

Opificio delle Pietre Dure e Laboratori di Restauro, Viale F. Strozzi 1, 50129 Florence

During his Florentine sojourn, in the 1360s, Giovanni da Milano was commissioned to undertake the complete decoration of the First Sacristy of the Franciscan Church of Santa Croce. The chapel, now known after the later patron, the Rinuccini family, was supposed to be decorated with a fresco cycle (*Stories of the Life of the Virgin and of Saint Mary Magdalen*), completed by a panel painting hanging from the keystone (and possibly an altarpiece). For unknown reasons Giovanni da Milano didn't complete the *entreprise* and a different artist was responsible for the lower register. In the eighteenth century the chapel underwent a huge restoration treatment by Agostino Veracini, who severely repainted many areas and added several figurative elements. When the additions on the frescoes were removed in 1959, doubts arose about the authorship of the tondo in the keystone, whose brilliant state of conservation seemed too fresh to date from the fourteenth century. The recent monographic exhibition on Giovanni da Milano, held in the Galleria dell'Accademia Florence, offered us a unique opportunity to reconsider the technical execution of the artworks within the Rinuccini chapel.

Whilst scientific studies undertaken on the panel painting, re-establishing the authorship of Giovanni da Milano, were published in the catalogue of the exhibition, our conclusions regarding the investigation of the wall paintings are yet to be disclosed. Examination of the frescoes was both non invasive (IR false colour, IR b/w, UV fluorescence, XR fluorescence) and invasive, (stratigraphic studies of samples). The astonishing results encouraged us to study the similarities between Giovanni da Milano's wall painting and panel painting techniques. Results revealed that in both cases the artist used identical materials, identical painting techniques (i.e. for the gilded decorations), identical textures in his brushstrokes, identical paint layer structures, as well as identifying an uncanny similarity in his research for specific aesthetic effects; details common to panel paintings yet unknown on wall paintings. Indeed, the frescoed cycle of Giovanni da Milano displays a large range of techniques generally unheard of on wall paintings. An explanation for this peculiarity can be attributed to the possible northern artistic training of Giovanni da Milano maybe primarily focused on panel painting. To prove our point we can highlight the technique used to reproduce flesh tones: a fine interweave of subtle brushstrokes used to build volumes and texture, which is typical of panel painting technique, but unknown on wall paintings.

As an interesting note we can add that scientific investigation undertaken on the panel painting on the tondo, shows that Giovanni da Milano used calcium caseinate as a binder for his pigments. In our opinion this was a conscious choice by the painter in order to render his work slightly opaque and in harmony with the surrounding wall paintings. An additional clue suggesting this intention is the fact that he never varnished the panel.

The unusual similarities between Giovanni da Milano's panel painting and wall painting techniques constitute a rare and unique case study which will be the core discussion of our paper.

Neroccio's *Virgin and Child with Saint Anthony Abbot and Saint Sigismund* at the National Gallery of Art, Washington

Carol Christensen, Michael Palmer, Suzanne Lomax, and Steve Wilcox

National Gallery of Art, Washington

This large panel painting, a late work (c.1492-6) by the Sienese painter Neroccio dei Landi, recently underwent technical investigation to better understand the artist's working procedure, to resolve questions about later alterations, and to help determine the best course of treatment for the painting. Although located in the church of the former hospital of San Bartolomeo, San Rapolano, by 1865, the picture was probably not commissioned for this site, and its original home is unknown. The present rectangular format is a nineteenth-century alteration; the originally diagonal upper corners presumably formed a gable crowned by a God the Father image, as in Neroccio's still extant Montisi altarpiece of 1496. No other paintings by Neroccio have been associated with this work, which presumably was the central panel of a larger altarpiece.

X-radiographic examination suggested that very early in the execution of the picture the diagonal top right and left edges were enlarged slightly, presumably to accommodate a change in the dimensions of the commission. Infrared reflectography revealed a surprisingly broad and bold underdrawing quite unlike Neroccio's thinner more tentative style. The underdrawing is more typical of the style of Francesco di Giorgio, Neroccio's partner of twenty years earlier, suggesting the two artists may have renewed their partnership for this project, with Francesco, recently returned from Urbino, providing the design and drawing that Neroccio completed in paint. Neroccio's use of incised lines for demarcating the folds in the Virgin's robe and the outline of the Child as well as his use of mostly tempera paint demonstrate his essentially conservative working procedure at a time when many of his contemporaries were switching to oil medium. Although he painted one area, the red robe of Saint Sigismund, in oil or an oil-tempera mixture, he applied it with the discrete brushstrokes of the tempera technique, suggesting that he either did not completely understand the blending advantage of the oil medium or preferred to apply the paint in a consistent manner throughout.

While medium analysis using GC-MS and staining of cross-section samples was able to suggest some degree of differentiation between areas painted in tempera and those painted in tempera grassa or oil, the analysis was complicated by the presence of both old oil-resin and glue surface coatings, so these identifications can be considered only approximate. Pigment analysis included examination of intact chips, scanning electron microscopy/energy dispersive X-ray spectroscopy and characterization of dispersed samples using polarized light microscopy. Technical investigation determined that the dark surface coating containing separate layers of degraded oil-resin, glue, and natural resin varnish was not original. The conservation treatment involved removal of these coatings and

reconstruction of damaged punched gilding along the top diagonal edges. The painting was found to be unusually well preserved, especially in the flesh areas, although the deep reds in the shadows of Saint Sigismund's robe have faded significantly.

New examinations on Giovanni Bellini's Pesaro Altarpiece. Novelties and comparisons with other Bellini works

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A large campaign of analyses, mainly non-invasive such as infrared reflectography, false colour IR, X-ray fluorescence (ED-XRF), and reflectance spectrometry (vis-RS), has been conducted by a team of Italian Universities during the last nine years on works of Giovanni Bellini, with the aim of improving our knowledge of this master's painting technique, and sometimes also to support restorations. During this project, more than 50 paintings of Bellini and his workshop have been studied, usually *in situ*, and among them some masterpieces like the paintings of the Accademia Carrara of Bergamo and the Gemäldegalerie SMPK of Berlin, and the altarpieces remaining in the churches of Venice and Vicenza, as well as the Pesaro altarpiece.^{1,2}

The large database acquired – joined with the analyses published by different laboratories during the last thirty years – allows proper comparisons and the possibility to trace the evolution of Bellini's technique through the decades, together with a preliminary definition of the characteristics of the workshop.

In particular, we focus the attention on the Pesaro altarpiece, a work which is very representative of Bellini's technique and a crux in the history of Italian painting, probably painted shortly before 1475, a little time before Antonello da Messina spent his year in Venice (1475-1476). The palette Bellini employed for this work is significantly very large, including almost every pigment available on the Venice market. This was clarified by the new non-invasive examinations by XRF and vis-RS on hundreds of sample points, which showed some pigments that were not individually identified in the published cross-sections studied 20 years ago.^{3,4} Among them, a zinc-rich, copper blue pigment was found in the Virgin's cloak, under the lapis lazuli final layer, and indigo was found, alone or mixed with lead-tin yellow and lead white, to obtain the green colours of some marbles. On the contrary, we didn't find evidence of smalt blue in the Virgin's cloak, a pigment that we could detect in the blue cloak of another painting of the period, the *Virgin with Child (Madonna Lochis)* of Bergamo.⁵ Evidence of indigo, alone and in mixtures, to obtain blue-

¹ Poldi, G., and Villa, G. C. F., 'Giovanni Bellini e dintorni, ovvero Appunti veneziani', in *Dalla conservazione alla storia dell'arte. Riflettografia e analisi non invasive per lo studio dei dipinti*, Edizioni della Normale, Pisa (2006) 321-412.

² *Giovanni Bellini. Sette opere indagate nel loro contesto*, eds. G. Poldi and G. C. F. Villa, Silvana Editore, Cinisello Balsamo (2008).

³ Laurenzi Tabasso, M. (coord.), 'Le indagini scientifiche', in *La pala ricostituita. L'Incoronazione della Vergine e la cimasa vaticana di Giovanni Bellini. Indagini e restauri*, ed. M. R. Valazzi, Marsilio, Venezia (1988) 127-143.

⁴ Dunkerton, J., 'Bellini's Technique', in *The Cambridge Companion to Giovanni Bellini*, ed. P. Humfrey, Cambridge University Press, Cambridge (2004) 195-225.

⁵ Poldi, G., and Villa, G. C. F., *Indagando Bellini*, Skira, Milano (2009).

green colours in other paintings by Giovanni and Gentile Bellini are discussed, as well as the use of azurite and/or lapis lazuli for the skies of the *predella*, and the use of orpiment and realgar for orange and yellows.

The new IR examination revealed not only the wonderfully detailed and hatched underdrawing, made with a thin paint-brush, typical of Bellini at this age, but suggested that the saints of the small pillars were painted before the main scene with the *Coronation of the Virgin*, and partially clarified the evolution of the complex project.

The 'Uomini Illustri' portraits in the *Studiolo* of the Ducal Palace of Urbino

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The 28 portraits of the 'Uomini Illustri' were originally painted for the *Studiolo* of Federico da Montefeltro (1422-1482) in the Ducal Palace of Urbino. Associated in seven poplar panels with four portraits each, the collection was cut into 28 easel paintings shortly after the Duke's death and brought to Rome. 14 portraits were acquired by Marquis Campana and arrived at the Louvre Museum in 1863, whereas the other 14 are actually exhibited in their original location in the Urbino *Studiolo*.

The attribution of the paintings has already been the subject of extensive research that resulted in the proposal for a joint contribution by the Flemish painter Juste de Gand and the Spanish Pedro Berruguete.

On the occasion of the conservation work undertaken on the 14 Louvre portraits in the 1980s, an analytical campaign was performed which confirmed the hypothesis that Juste de Gand was the master who first executed all the paintings, which were later modified by Pedro Berruguete who also adopted different painting materials and execution techniques.

Recent research studies are being carried out on the overall painting collection with the aim of better clarifying the original placement within the *Studiolo*, the number of painters involved and the attribution and painting technique adopted. A complement of non-destructive techniques (multispectral imaging, infrared reflectography, X-radiography and X-ray fluorescence) and extensive analyses of microsamples (optical, FTIR, Raman and scanning electron microscopy) brought to light significant results. In fact, the so far accepted organization is slightly modified, the execution of the overall collection better understood and the contribution of more than two painters evidenced thanks to the contribution of the complement of analytical techniques used.

Lavalley, J., 'Le Palais Ducal D'Urbino', Les Primitifs flamands, Corpus de la peinture des anciens Pays-Bas méridionaux, Bruxelles (1964).

Martin, E., 'Assistance scientifique à la restauration, un exemple: Les portraits d'hommes illustres du Studiolo d'Urbino', *Techne* 2 (1995) 129-134.

Raynaud, N., and Resson, C., 'Les portraits d'hommes illustres du Studiolo d'Urbino au Louvre par Juste de Gand et Pedro Berruguete', *Revue du Louvre et des Musées de France* I (1991) 82-113.

Michelangelo's 'Doni Tondo' investigated with non-invasive analytical techniques

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More than twenty years after intervention on Michelangelo's panel, it has been decided in collaboration with the Uffizi Gallery to take advantage of the important evolution that non-invasive methods of investigation have since undergone. A campaign of analysis was therefore undertaken by means of various techniques, some of which had already been employed prior to restoration. The aims were to clarify certain aspects which had remained partially unresolved, because of the technical limitations of the methods at the time, by integrating analysis using more recently developed techniques, and not least also to determine and compare the state of the work after a significant length of time.

The various institutions involved were: for X-radiography of the painting and frame, RGB imaging, and chemical analysis, Opificio delle Pietre Dure e Laboratori di restauro, Firenze (OPD); IR scanner reflectography, Istituto Nazionale di Ottica Applicata, Firenze (INOA-CNR), OPD; X-ray fluorescence, Ente per le Nuove tecnologie, l'Energia e l'Ambiente, Roma (ENEA); image spectroscopy and fiber optic reflectance spectroscopy, Istituto di Fisica Applicata "Nello Carrara", Firenze (IFAC-CNR). Investigation was carried out in the fall-winter months of 2008-2009, and included taking full-scale single shot X-rays of both painting and frame, colorimetric analysis (FORS), spectroscopy by means of a hyperspectral scanner (IS), IR scanner reflectography, multi-spectral imaging in the 360-950 nm range and relative false colour imaging, XRF analysis.

This paper presents a comparative and integrated report and interpretation of the results of investigation, carried out by a number of experts in the various fields. Results have proved to be of great interest, supplying a considerable amount of new information, for example regarding the phase of preparatory drawing during the making of the painting. We believe this may be particularly important in contributing to the study and understanding of the work of such a great master and of his painting techniques, so important to understand in relation to this crucial moment in the evolution of painting techniques in general.

Granacci in The Metropolitan Museum of Art; aspects of evolving workshop practice

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In recent years, The Metropolitan Museum of Art has acquired four paintings by the Florentine painter Francesco Granacci (1469-1543) and his workshop. Created between 1500 and 1525, these works provide a valuable opportunity for comparative technical examination, spanning the transition in this artist's work from egg tempera to oil, and as a study in contemporary workshop practice. This paper will present the findings of the examination and analysis of the four paintings, *The Crucifixion*, *Scenes from the Life of Saint John the Baptist*, *Saint John the Baptist Bearing Witness* and *Madonna and Child*, undertaken jointly by the Paintings Conservation and Scientific Research departments of the Metropolitan.

Scenes from the Life of Saint John the Baptist and *Saint John the Baptist Bearing Witness* (both c.1505-10) make a particularly interesting comparison, as two works from a cycle depicting scenes from the life of the saint whose evident stylistic disparities were noted as early as 1878. Until the recent examination, the degree to which materials and technique account for the difference in their appearance had not been explored. *The Scenes from the Life of Saint John the Baptist* has the character and structure of a traditional egg tempera painting; analysis shows that the egg yolk medium has an additional drying oil component. *Saint John the Baptist Bearing Witness* was found to be painted in pure drying oil medium, allowing an image with a broader range of tone, and rich, saturated colour. Samples from both paintings show the formation of lead soaps in areas containing lead tin yellow type I. While lead soaps have been associated with lead tin yellow pigment in oil paint, their presence in tempera paint has been less studied, and so this occurrence is of particular interest. The Metropolitan's two other paintings by Granacci are chronological and technical bookends to the Saint John panels: a small triptych, *The Crucifixion* (c.1500-10), painted in pure egg tempera, and the *Madonna and Child* (c.1525), painted in pure drying oil, with a technique closer to Netherlandish oil painting, using body colour and glazes.

The underdrawings of the paintings, as revealed by infrared reflectography, vary in their character and function in the individual works. This too will be discussed in the context of workshop practice.

**Leonardo da Vinci's *The Virgin and Child with Saint Anne* (Paris, Louvre):
New infrared reflectography**

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A scientific study of Leonardo da Vinci's *The Virgin and Child with Saint Anne* (Paris, Louvre) has been carried out by the C2RMF in September 2008. As part of this study, an infrared reflectogram of the whole painting has been made with a newly acquired Osiris infrared camera, a device developed with the assistance of the London National Gallery scientific team.

The image brings a great amount of new information concerning this masterpiece. It allows a better understanding of the actual composition; it shows several kinds of underdrawing as well as some unnoticed composition changes. It sheds a new light about the hypothesis of a lost cartoon and may lead to an interesting confrontation between the Paris painting and the London cartoon.

The paper will also present the three hitherto unknown drawings discovered on the back of the panel with the help of infrared reflectography.

Leonardo da Vinci's *Virgin of the Rocks*: Technique and the context of restoration

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After several years of research into the feasibility and safety of conservation treatment, the Trustees of the National Gallery gave permission in November 2008 for Leonardo's *Virgin of the Rocks* to be cleaned and restored. The work was begun by one of the authors (Larry Keith) soon after. By the time of the 'Technical Bulletin Anniversary Conference' in September 2009, the work will be far advanced, both in terms of the restoration itself and also the supporting analytical and technical studies. The work has been undertaken for aesthetic reasons primarily - that is to enhance the visitors' appreciation of a picture that had become increasingly difficult to 'read' as the result of the drastic degradation of the oil and mastic varnish which had been applied in 1949. It was anticipated at the outset that the legibility of the painting would increase greatly on cleaning and that the subsequent restoration would provide further clear visual gains. At the same time, knowledge of Leonardo's practice will expand in tandem, as a result of the associated studies of his methods and materials and those of comparable pictures. These advances of technical interpretation are particularly relevant to the case of the *Virgin of the Rocks*, where the finer points of authorship and the distribution of labour between Leonardo and his associates, as well as the nature of the relationship between the London and Paris versions of the composition, are central issues. This has already been demonstrated to a notable degree by discoveries made during infrared reflectography undertaken in 2005,¹ and our understanding of the picture has been significantly developed by the wider range of investigative and analytical techniques deployed in the course the present campaign of restoration. The preliminary results of these investigations will be presented.

It is now widely accepted that the knowledge gained from a conservation project of this type can make an important contribution to a much fuller understanding of the picture - one which is naturally integrated into wider art-historical evaluation. This methodology, however, would not have come as easily to those involved in the restoration campaign of 1948-49, nor were the whole range of techniques of investigation or documentation available then. It is also instructive, we believe, to compare the professional context of the two most recent campaigns - particularly on the occasion of the thirtieth anniversary of the *Technical Bulletin* - as a means of thinking about the evolution not just of the process of restoration, but its larger function or purpose in the ways in which we come to interpret the pictures themselves.

¹ Syson, L., and Billinge, R., 'Leonardo da Vinci's use of underdrawing in "The Virgin of the Rocks" in the National Gallery and "St Jerome" in the Vatican', *The Burlington Magazine* 1228 (July 2005) 450-463.

In quest of vermilion: The production, commerce and use of the pigment in eighteenth-century Spain

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The importance of the Almaden mine (Spain) in the production and commerce of vermilion is well known. The cinnabar mine was working at full capacity from the Roman Empire until the end of the twentieth century (mercury and vermilion). A common aspect during all these centuries was the establishment of protectionist practises for the exploitation of the mine and the commercialization of its products. These practises had important economic consequences regarding the price of vermilion, but not regarding its quality. The pigment was sold in two forms: the so-called *bermellón piedra* (*stone vermilion*), a guarantee of purity; and the *bermellón molido* (*ground vermilion*), subject to adulteration. This situation changed drastically when in 1727 the free trade and importation of cinnabar, as well as the production of artificial vermilion, was forbidden. The sale of the pigment was only allowed through *estancos*, the state authorized establishments.

This had an important impact on painting. It seems that, traditionally, Spanish painters preferred the artificial vermilion to the natural one. Furthermore, the production of *bermellón piedra* was concentrated in Seville, and then it was transported to Madrid, where it was sold only as *bermellón molido*; adulterating vermilion with red lead seemed to be the ordinary practice in Madrid, as is apparent from the list of production costs of 1739. This situation alarmed painters and prompted their protest to the King in 1728. There, they stressed the bad quality of the vermilion sold at the *estancos*, adulterated even up to 50% with red lead. Despite these problems, documentary sources testify that the use of *bermellón de estanco* was the common practice for the majority of painters, like Goya, Bayeu or Maella. But master painters, principally the ones that worked for the Spanish Crown, had the possibility to avoid the law. For example, Mengs specifically asked for *bermellón de Holanda* in order to paint the copies for the royal tapestries. This quest for good vermilion for use in paintings ended when the trade of natural vermilion from China was authorised in 1777, although its price and sale was also controlled by the state *estancos*.

The authors will study the production methods of the so-called *bermellón piedra* from the mineral cinnabar, based on documentary sources of the sixteenth to eighteenth centuries. The impact of the protectionist regulation on the painting *praxis* will be also analyzed. Finally, the accessibility of good vermilion can highlight the difference in situation of common painters as opposed to masters and might constitute an important source for the interpretation of painting techniques in eighteenth-century Spain.

The rediscovery of sublimated arsenic sulphide pigments in painting and polychromy: Applications of Raman microspectroscopy

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Dry-process arsenic sulphide pigments in painting and polychromy has been a topic of interest since historic and modern samples termed 'artificial orpiment', 'King's yellow' or 'Gelbglas' were identified to contain sublimated crystalline arsenolite (As_2O_3), amorphous arsenic sulphide glass spherules (g- As_xS_x) up to 70 μm \emptyset and subordinately crystal aggregates of alacranite ($\text{As}_8\text{S}_{9-x}$) in the form of spherules of up to 30 μm \emptyset . Samples labelled 'artificial realgar', 'ruby arsenic' or 'Rotglas' revealed a mixture of amorphous arsenic sulphide glass (g- As_xS_x) and subordinately alacranite ($\text{As}_8\text{S}_{9-x}$) with spherules of up to 30 μm \emptyset .

The history of manufactured arsenic sulphide pigments has been one of misapprehensions, mistaken identity and etymological confusion. On the basis of new determination criteria and evidence of striking conformity, artificial arsenic sulphides produced with dry-process methods (roasting and/or sublimation) have been detected in the paint layers of the following artworks: 1) sixteenth/seventeenth-century polychrome recumbent sculpture 'St. Alto' (Altomünster, South Germany) with a pigment classified as 'complex artificial orpiment'; 2) seventeenth-century painting attributed to Rembrandt's studio ('Man with the Red Cap', Museum Boijmans van Beuningen, Rotterdam) with a pigment classified as 'purified artificial orpiment glass'; and 3) painting by Jan Davidszoon de Heem ('Still Life of Flowers and Fruits with Tazza and Birds', early 1670s, private collection). The identification and characterisation of the crystalline and amorphous constituents required the use of microscopic methods as well as SEM-EDX/WDX, EBM, XRD and Raman analysis. Raman microspectroscopy proved to be an essential tool particularly for: 1) the differentiation between realgar, pararealgar and alacranite of almost identical chemical composition; 2) the determination of particles as small as 10 μm \emptyset ; and 3) the distinction of x-ray amorphous arsenic sulphide glasses.

To date the following main components of artificial arsenic sulphides have been identified in painting and polychromy: 1) g- As_2S_3 – yellow, transparent to translucent splintery

fragments and/or complete spherules of orpiment glass; 2) $g\text{-As}_x\text{S}_x$ – reddish orange to red-brown, transparent to translucent splintery fragments and/or complete spherules of arsenic sulphide glass; 3) As_2S_3 – golden yellow, transparent to translucent platy fragments of natural orpiment with a smooth surface as relics in molten arsenic sulphide cake; 4) $\text{As}_8\text{S}_{9-x}$ – reddish orange, radial grown alacranite aggregates in the form of spherules and splintery fragments; 5) As_4S_4 – yellow to orange-brown, spherules and/or splintery fragments of pararealgar; and 6) As_2O_3 – colourless, transparent irregular fragments and/or octahedral crystals of arsenolite. Furthermore, new Raman analysis also confirmed that pararealgar – a light-induced transformation product – is not exclusively linked with natural realgar, but can also form on members of the alacranite solid solution series ($\text{As}_8\text{S}_{9-x}$).

Artificially prepared yellow and red arsenic sulphides are described as important colourants in numerous historic documentary sources (e.g. painting treatises). That poses the intriguing question – where have the hundreds of tonnes of arsenic sulphides gone? We propose that many of the ‘natural’ arsenic sulphides that have been identified in painting and polychromy will turn out to be of artificial origin.

The use of blue and green verditer in green colours in seventeenth-century Netherlandish painting practice

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During a large-scale technical study of the paintings in the *Oranjezaal* (the central hall) of the Royal Palace Huis ten Bosch in The Hague (1648-1652), special attention was paid to the composition of the green paints used by the twelve artists for painting garments and foliage. Small blue/green copper-containing pigment particles showing a typical spherical shape were found remarkably often in paint cross-sections of these green paints. Ten of the twelve painters used this pigment, including Jacob Jordaens, Gonzales Coques and Caesar van Everdingen. In some paint cross-sections the particles are sparsely distributed throughout the paint layer, the bulk of the layer containing other pigments. In other cross-sections their packing is very dense. These spherulitic particles are mixed with yellow pigments (yellow lake, lead-tin yellow and/or yellow ochre) and often with smalt, with additions of carbon-based black, red ochre and lead white to obtain a variety of colour tones. In general, the green colour is surprisingly well preserved.

The characterisation of the small spherulites was particularly challenging. About 20 paint cross-sections were analysed using SEM-EDX, in some cases complemented with FTIR imaging and Raman spectroscopy. SEM-EDX gained insight into the particle shape and size, and the presence of other trace elements apart from copper. FTIR imaging revealed absorption bands attributable to the carbonate group, while the Raman spectrum closely correlated to a reference sample of blue verditer, an artificial copper carbonate. It was found that the true colour of the verditers could not be determined with light microscopy alone, since the particles are embedded in a yellow/brown matrix that makes fine blue particles appear greenish.

From contemporary sources it is known that the difference between blue and green verditer was not very distinct. The terminology used in the treatises by, among others, Théodore de Mayerne, Willem Beurs and Jan Davidsz de Heem, illustrates the confusion. The term verditer – *verd de terre*, *verddeterre* or *terra verda* – can refer to both blue and green verditer, though the name suggests a green pigment. The confusion in terminology must result from the inconsistency in colour and colour intensity of the traded product. The seventeenth-century verditers were artificially prepared, primarily in England, and were a by-product of the silver refiners’ craft. The technology by which they were manufactured was not well understood at the time, resulting sometimes in a more bluish colour and sometimes in a more greenish colour. It is possible that smalt was added to make the colour appear bluer. However, it has also been suggested that smalt intensifies the green colour and was added to green pigment mixtures for that reason. The effect of the addition of smalt to oil paints

containing green or blue verditer was further explored via paint reconstructions. This also provided valuable information on the optical properties and colour intensity of both green and blue verditer in oil. The abundant use of verditers in the *Oranjezaal* suggests that these pigments were more commonly used in seventeenth-century Netherlandish painting practice than was previously thought.

Alterations in paintings: From non-invasive *in-situ* assessment to laboratory research

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Non-invasive studies of immovable artworks, such as monuments, architecture, sculptures, and mural paintings, require mobile scientific equipment for non-invasive *in-situ* diagnostics. Mobile equipment is also indispensable for studies on artworks that in principle could be moved to a laboratory, but in practice are never moved from their location for security reasons, as occurs in the case of precious paintings.

The mobile laboratory MOLAB has been accessible to European users, in the last five years, for *in-situ* non-invasive studies of paintings and other objects. It consisted of a unique collection of portable equipment composed of prototypical or state-of-the-art tools, including a scanning IR-colour imager, a laser micro-profilometer, a fibre-optic near- and mid-FT-IR spectrometer, a compact micro-Raman, a single-sided NMR relaxometer, a portable UV-Vis fluorescence system, etc., belonging to four joint Italian institutions, namely: University of Perugia, Opificio delle Pietre Dure, Istituto Nazionale di Ottica Applicata (CNR-INOA) and Istituto per la Conservazione e Valorizzazione dei Beni Culturali (CNR-ICVBC). The laboratory has been open to Transnational Access within the Eu-ARTECH project of the 6th Framework Programme of the European Union.¹

MOLAB facilities have been applied to several non-invasive studies of prestigious paintings^{2,3,4} including works by Perugino, Raphael, Leonardo, Antonello da Messina, Memling, Renoir, Cezanne, Mondrian, Rothko, and others; medieval illuminated manuscripts such as the 'Book of Kells' and the 'Psalter Manuscript'; and Roman mural paintings and Egyptian mummy portraits.

The possibility of extensive studies on numerous artworks offered the opportunity to extend to real cases the knowledge achieved through laboratory studies on the alteration of painting materials and, *vice versa*, allowed us to find new problems to be put under the focus of laboratory research.^{2,3,4}

At the conference, different cases of formation of oxalate patinas on paintings will be presented and the causes of formation of whitish alterations on the surface of *encausto* paintings will be discussed. The results will be presented in relation to real cases.

¹ See <http://www.eu-artech.org>.

² Brunetti, B.G., Seccaroni, C., and Sgamellotti, A., *The Painting Technique of Pietro Vannucci, called Il Perugino*, Proceedings of the LabS TECH Symposium, Quaderni di Kermes, Nardini Editore, Firenze (2004).

³ Roy, A., and Spring, M., *Raphael's Painting Technique: Working Practice before Rome*, Proceedings of the National Gallery Symposium, London, Quaderni di Kermes, Nardini Editore, Firenze (2007).

⁴ Miliani, C., Kahrim, K., Brunetti, B.G., Sgamellotti, A., Aldrovandi, A., van Bommel, M. R., van den Berg, K. J., Janssens, H., 'MOLAB, a mobile facility suitable for non-invasive *in-situ* investigations of early and contemporary paintings: the case-study of Victory Boogie Woogie by P. Mondrian', *Proceedings of the 15th Triennial Conference of ICOM-CC, New Delhi* (2008) and references therein.

Technical study of the *Altopiece from the Cathedral at Ciudad Rodrigo* by Fernando Gallego and his workshop

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Fernando Gallego's altarpiece for the Ciudad Rodrigo Cathedral is widely considered one of the most important Spanish altarpieces of the late fifteenth century. Since 1957, however, when the Kress Foundation donated the twenty-six remaining panels to the University of Arizona Museum of Art, the altarpiece has resided in Tucson, Arizona, a location that was inaccessible to many Gallego scholars, and many questions about its creation remained unresolved. Even the authorship of the panels was debated, because Gallego's workshop collaborated with that of the Maestro Bartolomé, a brilliant but relatively little-known painter.

The present technical study was initiated to learn more about the workshop practices that produced the altarpiece, especially the division of labour within the workshops and the relationship between them. Because so few documents relating to the artistic commissions survive from fifteenth-century Castile, little was known about these practices. Furthermore, after the altarpiece was removed from the cathedral in the late sixteenth century, some of the panels and the framework were lost, destroying evidence of the original number of panels and their arrangement. It was hoped that new information gleaned from a direct examination of the panels themselves would shed light on these issues.

The Ciudad Rodrigo examination used as a starting point research presented at the 1998 Dublin conference in the ground-breaking paper by Sam Hodge, Marika Spring and Ray Marchant *The Construction and Painting of a Large Castilian Retable A Study of Techniques and Workshop Practices*. But while the Hodge study centred on a complete altarpiece preserved *in situ*, the Ciudad Rodrigo study addressed the challenge of examining an incomplete altarpiece, removed from its original location. In 2006 the Ciudad Rodrigo panels were sent to the conservation studio of the Kimbell Art Museum in Fort Worth, Texas, for a comprehensive technical examination under the direction of Claire Barry, Chief Conservator of Paintings. With Elise Effmann, then assistant conservator, Ms. Barry carried out infrared reflectography on all twenty-six panels, revealing the elaborate brush underdrawing of Gallego and his fellow artists. This represented the most comprehensive group of underdrawings of Gallego's panels ever published to date and the only published underdrawings of the Maestro Bartolomé, offering a rare glimpse into drawing style and practices in fifteenth-century Castile. The technical study also included X-radiography, pigment and medium analysis, the latter with the aid of Inge Fiedler from the Art Institute of Chicago and Michael Schilling at the Getty Conservation Institute. Throughout the project, the conservators collaborated closely with Gallego scholars.

The study revealed insights into the organization of the workshops of Fernando Gallego and the Maestro Bartolomé. Their individual studios used separate means to streamline production. One workshop used colour notes, while the other borrowed compositional elements directly from northern prints. Evidence of the use of shared assistants for background details such as trees and figures, however, also suggested there was some fluidity between the two workshops.

Albrecht Altdorfer's *Crucifixion* (Budapest, Museum of Fine Arts)

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Albrecht Altdorfer's (c.1480–1538) remarkable technique and dynamic style attracted sophisticated patrons, both within his hometown of Regensburg and across the Danube region. Among his most important benefactors was the provost of the Augustinian Abbey of Sankt Florian, Peter Maurer, who commissioned the multi-part *Saint Sebastian* altarpiece (completed c.1520; St. Florian and Vienna, Kunsthistorisches Museum) from the artist. This paper considers Altdorfer's *Crucifixion* (c.1518; Budapest, Museum of Fine Arts), the magnificent devotional painting Maurer ordered for his own private chapel.

A dramatic scene that juxtaposes the moving figures of Christ and the suffering Virgin with a mass of coarse spectators - delineated in great detail - at the foot of the cross, the painting is most notable for its *retardataire* gold background. Painted on the cusp of the tumultuous religious crisis that would sweep the region, it is the only gold ground painting in Altdorfer's oeuvre. Surprisingly, the Budapest *Crucifixion* has received little attention from scholars, and the appearance of two different types of gold in the background was generally accepted as original.

The painting was sent to the Paintings Conservation department at the J. Paul Getty Museum in Los Angeles for study and treatment in the spring of 2008. The picture was covered with an exceptionally thick and discolored varnish, and numerous campaigns of retouching had become unsightly. Structural treatment of the panel was also required.

Technical studies were undertaken to gain a better understanding of Altdorfer's working methods and materials, and to clarify some questions concerning the original appearance of the gilt background. Infrared reflectography revealed Altdorfer's characteristically extensive - and ebullient - underdrawing. The elemental composition of the various colours in the painting was determined using X-ray fluorescence (XRF) spectroscopy. Cross-sections were taken in order to determine the stratigraphy of specific areas; the elemental composition of the individual layers within each sample was analyzed with scanning electron microscopy energy dispersive spectroscopy (SEM-EDS). Micro-Raman spectroscopy was also employed. These results will be compared to those acquired on additional paintings by Altdorfer at St. Florian's near Linz, Austria, conducted using the Getty Conservation Institute's portable XRF spectrometer.

Analyses confirmed that the gold sky (with clouds) which had been painted over the entire background, was in fact a later addition, added most likely as a means of disguising a vertical split in the panel.

Cleaning revealed a beautifully preserved paint surface, and the original gilding was found to be intact underneath the applied 'sky.' Interestingly, a ghost pattern of a decorative motif was found to be visible in the original gilding. This motif bore striking similarities to another ghost pattern found previously in the Wurzach Altarpiece (c. 1430) in Berlin (Gemäldegalerie). A nearly identical - and fortunately still intact - pattern was found in a late 15th-century German illuminated manuscript in the Getty's own collection (the Altmunster Missal).

The study of Altdorfer's innovative amalgamation of tradition and innovation in the *Crucifixion* sheds light on how this complex artist invoked historical approaches, both technical and iconographic, to redefine religious painting at a crucial time.

Multiplicity, authenticity and chronology: An integrated evaluation of five images of Saint Francis by El Greco

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In Counter-Reformation Spain, El Greco was widely admired for his iconographically original and emotionally powerful depictions of Saint Francis. Of the several hundred paintings produced by El Greco and his workshop, approximately fifteen percent depict subjects of Saint Francis.

While acknowledging the significance of El Greco's images of Francis, modern scholars have argued fiercely about the authorship of individual pictures. A misguided assumption that only one version of each theme could be autograph often complicated these debates. Due to the lack of documentation, scholars relied primarily on stylistic analysis to establish authorship and determine a chronology for the multiple representations.

The use of scientific and imaging techniques can assist in the development of a more accurate understanding of the authorship and chronology of paintings of Saint Francis, associated with El Greco.

This project was initiated by a re-evaluation of the authorship of one of El Greco's most popular and influential Franciscan themes: *Saint Francis Kneeling in Meditation* (c.1595-1600), now in the collection of the Art Institute of Chicago. Since the 1960s, most scholars had accepted the judgment of Harold Wethey,¹ who classified the Chicago painting as a workshop product on the basis of its supposedly 'dull' colours.

The Chicago picture was thoroughly examined along with four other versions of the same image of Saint Francis.² The paintings are currently in the collections of the Museo de Bellas Artes de Bilbao; the Fine Arts Museums of San Francisco; the Palais des Beaux-Arts, Lille and the Meadows Museum, Dallas. The recent treatment revealed dynamic brushwork and demonstrated a consistency of the Chicago painting with the other four paintings despite its pre-conservation appearance. A comparison of pigments, binders and layer stratigraphy, X-rays and infrared imaging is discussed for the various versions. Among other matters, analysis confirmed that a consistent palette, with minimal variations, had been used for all the works. Further, the scientific identification of the materials is correlated with the writings of Francisco Pacheco and other contemporaneous commentators of the Golden Age of paintings in Spain.

¹ Wethey, H., *El Greco and His School*, 2 volumes, Princeton: Princeton University Press (1962).

² Mann, R. G., 'Saint Francis Kneeling in Meditation, 1595/1600' in *Northern European and Spanish Paintings before 1600 in the Art Institute of Chicago*, Yale University Press for the Art Institute of Chicago, Chicago (2008).

A revised chronology for the versions of *Saint Francis Kneeling in Meditation* is presented – taking into account the most current scholarship,^{3,4} which considers the blurring of the lines between *modelli* and *ricordi* in the artist's oeuvre. On this basis, a fluid evolution of the Chicago painting from a *ricordo* of an earlier version of the Saint to a *modello* for new commissions can be established.

In addition to illustrating how a seamless integration of art historical research together with technical study of paintings can synergistically lead to more assured determination of attributions and chronological sequence, this project presents new results on ground composition, illustrating its specific gypsum crystal morphology, and the description of a very complex imprimatura, a consistent mixture of eight to ten different pigments. An in-depth analysis of the layering and glazing of the greens, including the use of copper resinate green is also discussed.

An introduction to Murillo's late painting technique: *Christ healing the Paralytic at the Pool of Bethesda*

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The National Gallery's *Christ healing the Paralytic at the Pool of Bethesda* is one of a series of six paintings made by Bartolomé Esteban Murillo for the church of the Caridad in Seville, between 1667 and 1670. Each of the works illustrates a different Biblical Act of Mercy and, taken together, have long been considered the artist's masterpiece. Only two of the series remain in the Caridad; the other four are dispersed in major museums throughout the world.

The first aim of this paper will be to present a study of Murillo's late materials and technique, focussing primarily on *Christ healing the Paralytic at the Pool of Bethesda* and others within the series. We will compare and contrast our findings with other recently published studies on Murillo, and demonstrate the comparative complexity and subtlety of the later works. We will also set Murillo's late technique within the context of seventeenth-century Spanish painting as a whole.

The second aim of this paper will be to discuss the particular problems associated with conservation and study of the National Gallery painting. The occurrence of anomalous, roughly sketched (original) red and black lines over the architecture will be presented, and an explanation sought. We will also consider the artist's use of the blue pigment smalt, and how its degradation has affected the appearance of the painting. In connection with this we will consider the usefulness of early painted copies of paintings (of which there were many in this instance), and to what extent they may serve as an indication of the original appearance of a painting.

³ McKim-Smith, G., Del Carmen Garrido, M., and Fisher, S.L., 'A note on reading El Greco's revisions: a group of paintings of the Holy Family', *Studies in the History of Art* 18 (1986) 67-77.

⁴ Sánchez-Lassa, A., 'La Anunciación del Greco: Análisis Comparativo' in *La Anunciación de El Greco el ciclo del colegio de María de Aragón, Museo de Bellas Artes de Bilbao*, Bilbao (1997) 59-72

Caravaggio's underdrawing: A 'Quest for the Grail'?

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This paper addresses the problem of the supposed absence of underdrawing in Caravaggio's artistic practice. The early biographers of Caravaggio claimed the absence of underdrawing in his paintings; their statement seems to be confirmed by the lack of a corpus of paper drawings to be attributed to the artist.

Due to this assumption, technical investigations on Caravaggio's paintings have been usually addressed to the study of incisions (considered to be his primary compositional device), and have been performed almost exclusively by means of X radiography and raking light photos.

In addition, the typical reddish-brown *imprimitura* used by Caravaggio (increasingly towards the end of his career) has not always encouraged the idea of using IR reflectography on his paintings.

Recently, rather bizarre conjectures have been ventured about a possible alchemic composition of Caravaggio's typical *imprimitura* that could have made his canvases similar to a daguerreotype plate, in order to allow him to create a compositional scheme from a living model under a lamp projection. At this stage of things, some sound research on the matter would be highly desirable.

The INOA high resolution IR scanner has recently produced good results in search of traces of underdrawing in Caravaggio's oeuvre, focusing the research to some specific paintings, and areas where he used a lighter *imprimitura*: as in the *Bacchus* of the Uffizi Gallery, the *Amor vincit omnia* of the *Gemäldegalerie* in Berlin, the *Rest from the Flight in Egypt* and the *Saint John the Baptist in the Wilderness*, both in Rome.

The results are very interesting and encourage further investigation: the finding of traces of drawing (possibly both tracing from a carbon-copy cartoon and some freehand elaboration) allows new consideration of Caravaggio's artistic practice, partly linked to a traditional artistic practice. This is not totally surprising, since the production of many replicas and copies in Caravaggio's workshop was certainly based on craftsman organization that was more traditional than his innovative artistic production could allow us to imagine.

Between creativity and economy: Remarks on Rubens's panel supports in the Royal Museums of Fine Arts of Belgium

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A four-year research project on paintings by P. P. Rubens and his circle at the Royal Museums of Fine Arts of Belgium in Brussels (RMFAB) uncovered important new information on the painter's studio practice. The diverse nature of the Brussels collection enabled the characterisation of several aspects of Rubens's technique. This paper discusses the supports of 26 paintings on panel from the RMFAB. The panels include preparatory sketches, portraits, mythological and religious subjects, spanning the years 1615 to 1637.

Rubens's panel supports have been well documented through case studies undertaken in several collections, and in particular at the National Gallery. These emphasise Rubens's varied choices of panel supports, especially his frequent enlargements of compositions and his apparently reckless selection of panels composed of small pieces assembled cross-grain to paint landscapes. These fragile panels are typical of Rubens's studio practice. The study of the Brussels panels addresses several other aspects of Rubens's choice of supports.

Five panels are marred by damages which were repaired with fillings before the application of the ground. The damages, invisible on the reverse, have become visible on the painted surface as they have caused distortions in the ground and paint layers with aging. One of these paintings, the *Portrait in a medallion of Don Gasparo de Guzman*, painted in preparation for an engraving by Pontius printed in 1625, also bears the monogram of the panel maker Michiel Vriendt as well as the Antwerp brand of the Burg and hands. This evidence prompts questions on the application of the 1617 joiners' guild regulations.

The quality of several of the panels is fairly poor, including tangentially cut planks, the presence of sapwood and even pith. These paintings are all by the hand of the master and some of them, such as the *Portrait of Paracelsus*, were likely part of his personal collection, raising the issue of Rubens's economical choice of supports of lesser quality for paintings initially meant to remain in his possession or in his immediate circle.

This economical approach is also noticeable in Rubens's cutting down standard-size panels to make smaller supports. The panels were probably bought already covered with a chalk ground and were further prepared in the studio with his typical stripy priming. They were then cut down to make smaller panels to paint preparatory sketches for larger formats.

Venus in the Forge of Vulcan is perhaps the most complex of Rubens's enlargements of existing compositions. A small core scene from around 1615 was integrated into a larger composition in around 1630 through the addition of a fragment of another painting and the lamination of the primary panel onto cross-grained plank. The resulting painting, drastically altered in the eighteenth century, is extremely fragile and prone to structural problems.

All cases are discussed within the wider context of recent research on seventeenth-century panel paintings from the southern Low Countries, involving dendrochronology, the study of wood technology and trade.

Travels with Peter Paul Rubens's *Last Judgement*

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In an interdisciplinary approach, we took a closer but unusual look at Rubens's *Last Judgement*, on view as the central masterpiece at the Alte Pinakothek in Munich. The painting's enormous size of 6.10 x 4.56 metres and estimated weight of 270 kg without and 500 kg with its gilded frame have continued to cause problems nearly everywhere it was presented in its long history. This conference paper travels to all these places, starting in Rubens's Antwerp studio and moving on to the Jesuit church in Neuburg, Danube for which the painting was commissioned; stops to take a look at the struggles ('the incarnate nakedness of the painted bodies') among the Jesuits at Neuburg; follows the painting's travels down the Rhine river after having been bought by Elector Jan Willem at Düsseldorf; traces its 'escape' into the quietness of Schleißheim castle in the Bavarian province; and finally considers the painting's eminent influence on the building and the lighting concept of the Alte Pinakothek concluding with a summary of its fate during World War II and its current presentation within the rebuilt Alte Pinakothek.

Although hosts of art historians have written about this masterpiece, its models and its subject, the *Last Judgement's* bumpy 2,000 km travel all around Europe on ships and horse carts, carried by menials and monks, are so-far untold. In particular, the implication of the large size on the respective architecture and questions of the where and how of its presentation at all the mentioned places have never been investigated. Starting at Rubens's studio, a closer look at contemporary etchings leads to valuable conclusions in regard to the artist's intentions for future lighting situations. Furthermore, our research allows for a new and better understanding of the work's presentation on the high altar at Neuburg, featuring a reconstruction of the original installation based on the examination of the site and on recently discovered archival material. A careful investigation of the architectural situations at Düsseldorf, Schleißheim and Munich gives new insights into the ways the painting was presented and received at the time. The paper covers the period from 1615 to today, i.e. from the creation of the *Last Judgement* to its current presentation.

Although one might think that the presentation of such a major painting is well documented, our research has given rise to numerous new questions in regard to handling, presentation and lighting. The paper proposes that future research on this and other major paintings should be far more open to including hitherto unconsidered archival material about the practical handling, shipping and trading routes, and to considering fare bills and tax receipts, travel accounts and visual documentation such as prints or watercolours of certain historical events such as weddings or funerals showing the artwork in its original site. This often neglected allegedly less important material will help to better understand and illustrate the history of an object, from its creation to the present day, and will add a fresh view to the appreciation of this art work. With this approach the paper aims to follow the admirable example set by all 29 numbers of the Technical Bulletin.

The Rosenberg Series 1618-1624: Painting techniques and painting materials supplied to the Royal Danish Court painters at the time of King Christian IV

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In the beginning of the seventeenth century the Danish King Christian IV ordered a series of large canvas paintings to decorate the Great Hall at Rosenborg Castle in Copenhagen. Originally, the series consisted of about 30 paintings of which approximately 15 paintings are still preserved and on display at Kronborg Castle in Elsinore. The Rosenberg Series forms a unique example of tradition and a strong early Dutch influence on painting techniques in Denmark at the beginning of the seventeenth century.

The large import of Dutch art works and a growing immigration of both Dutch and German painters into Denmark during the early seventeenth century became particularly influential in regard to the Rosenberg Series where at least five different painters from Germany, The Netherlands and Denmark were involved, including the Dutch painters Pieter (1569-1625) and Isaac Isaacsz (1599-1649) and the German painter Frants Clein (1582-1658).

A contemporary written source on painting materials handed out to painters and other craftsmen at the Royal Danish Court is preserved in its original form providing an opportunity for comparing technical findings in the Rosenberg paintings with a closely related written source. The documents consist of account books of the Royal Painting Materials Stores from the period 1610-1626. This unpublished account of materials handed out to court painters of ships and for interior decorations, as well as for commissioned paintings like the Rosenberg series, lists a broad assortment of pigments, oils etc.

In addition to the account books where no prices are mentioned, a Danish pharmacy price list from 1619, which has never been related to the court painters of Christian IV, holds valuable information, not only about materials available for Danish painters at the time but also offers prices for the listed pigments, metals and a variety of oils.

The paper discusses the written sources in relation to evidence on the painting techniques of the Royal Danish Court painters in the beginning of the seventeenth century based on technical and scientific investigations of the 15 Rosenberg paintings. Since the paintings were part of a single commissioned decorative scheme, created within a limited time-frame by several painters working for the Royal Danish Court, a comparison of their use of materials, especially those employed in the ground layers, have been carried out. 13 out of the 15 paintings, for instance, are painted on dark reddish grounds with obvious similarities.

The account books of the Royal Painting Materials Stores mention 9 different terms referring to blue pigments whilst usually only four different blue pigments were in frequent use during this period. Therefore, the paper furthermore discusses the use of blue pigments in the Rosenberg paintings in relation to the pigment terminology employed in the contemporary documents.

***Nine muses* in the Oranjezaal: Jan Lievens's and Caesar van Everdingen's painting methods confronted**

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The painted decoration of the Oranjezaal in Huis ten Bosch, offers a unique possibility to study the variation in style, painting technique and use of painting materials, as well as the interrelation between these technical and pictorial aspects, in mid-seventeenth-century Netherlandish painting. Twelve well-known artists from the Northern and Southern Netherlands painted the 44 paintings on canvas and architectural panelling in a short period of five years between 1648 and 1652. To establish the required unity in the ensemble, the painters were sent grounded canvases. Jacob van Campen, who invented and coordinated the decorative scheme, also provided the painters with detailed compositional sketches, including written instructions on the measurements of the figures, the perspective and the direction of light that had to be depicted.

Jan Lievens's *Five muses* and Caesar van Everdingen's *Four muses* hang on each side of the chimney. Together they depict the nine muses on the mount Parnassus. From archival records it is known that the commissioners considered the two paintings as *one* continuous representation. This is also evident from the paintings' compositions, which have been carefully tuned to one another by Van Campen to form a unified ensemble. However, despite their compositional uniformity, the appearance of the two pictures could not have been more different. Van Everdingen's painting is characterised by clear and luminous colours combined with an extremely sharp and detailed definition of the forms and a smooth paint surface wherein brush strokes are almost indiscernible. In Lievens's painting the forms have only suggestively been indicated using broad, spontaneous strokes and high paint relief.

Examination of the paint surface and cross-sections reveal that Van Everdingen and Lievens built-up their works in a complete different manner. They used a different type of underdrawing and dead-colour and they chose different paint layer structures, paint consistency, brushwork, use of contours etc. These divergent technical means were chosen by each artist to suit his particular pictorial purpose. For example, Van Everdingen achieved his luminous colours and sharply defined forms by a strict and rational painting procedure, using a very precise underdrawing, combined with an underpaint whose colours were carefully chosen with an eye to the final colour effect. Lievens's painting process, on the contrary, seems to have been open to much experiment. While applying his paint, this artist continuously kept searching for the 'correct' colour, tone and material effect. This implied

that Lievens sometimes worked for an extremely long time in certain zones, applying a great many layers that do not always seem to fulfil a function in the final result.

One wonders, whether the juxtaposition of two artists with highly different painting manners, for two paintings explicitly meant as one representation, was deliberately chosen by Van Campen. If so, the confrontation of painting styles must have been a significant theme in the Oranjezaal decoration.

Material as metaphor

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This paper seeks to mediate between scholarly methodology and intuitive artistic insight by considering painting practice in the light of neuroscience research. The paper considers a feature that is difficult to quantify or even to recognize: practices and materials that work allusively rather than purely descriptively. Examples of nonconscious and nonverbal cognition will be drawn from several studies of painting technique.

Since the early 1990s instrumental techniques including functional magnetic resonance imaging (fMRI) have been used to identify which brain structures are active during specific cognitive processes. Of particular interest for this paper is research that demonstrates differential brain activities in conscious and nonconscious thought and during verbal and visual processing.¹ This paper relates published literature to examples of painting practice, focusing on the cognitive processes known as 'priming' and 'pattern completion,' as well as recent research on the perception of metaphor. Priming and pattern completion trigger memories, often nonconsciously or nonverbally, when partial cues reactivate neuronal networks. In the case of metaphor neuroimaging suggests that different brain structures are active when processing literal meanings than those associated with resolving seemingly unrelated concepts into a meaningful metaphor.² While few studies have used fMRI to study art-making directly, this paper makes analogies between published neuroimaging studies and empirical evidence of the creative process.

Vermeer's use of dotted highlights seems to be an example of pattern completion. The similarity to the optical distortions seen in a *camera obscura* often has been cited as evidence that Vermeer used that device to compose his paintings. Technical limitations, however, would have made direct use of the device impractical within the studio,³ and physical evidence within the paintings confirms that Vermeer constructed perspective using a well-established procedure of strings pinned to the support.⁴ Yet the resemblance between Vermeer's soft, rounded highlights and the halation of highlights in a *camera obscura* must be more than accident. The visual characteristics of highlights in a *camera obscura* must have evoked Vermeer's memory of the round highlights he had painted on

¹ The overview of neuroscience in this abstract is indebted to Smith, E. E., and Kosslyn S. M., *Cognitive Psychology: Mind and Brain*, Prentice Hall, Upper Saddle River (2007).

² Pobric, G., Mashal, N., Faust, M., and Lavidor, M., 'The role of the right cerebral hemisphere in processing novel metaphoric expressions: a transcranial magnetic stimulation study,' *Journal of Cognitive Neuroscience* 20 (2008) 170-81; Schmidt, G. L., DeBuse, C. J., and Seger, C. A., 'Right hemisphere metaphor processing? Characterizing the lateralization of semantic processes,' *Brain and Language* 100 (2007) 127-41.

³ Liedtke, W., *Vermeer: The Complete Paintings*, Ludion, Ghent (2008) 179-89.

⁴ Wadum, J., 'Vermeer in Perspective,' in *Johannes Vermeer, exh. cat.*, National Gallery of Art and Toyal Cabinet of Paintings Mauritshuis, Washington and The Hague (1995) 67-69.

drapery in some of his earliest works; this partial cue would have reactivated an established neuronal network. Consciously copied halated highlights would appear only on reflective surfaces, as in the *camera obscura*.⁵ Instead, Vermeer appropriated dotted highlights in a loosely metaphoric sense when representing fabric surfaces.

Another example of nonconscious or nonverbal cognition is Rembrandt's technique of scratching into wet paint using a tool usually described as the end of the brush. Visual evidence, however, suggests that he sometimes used a reed pen, one of his preferred graphic tools. Rembrandt used this technique for bold, summary thinking analogous to his graphic work: for example, to clarify the structure of a landscape painting during the painting process. Choosing a pen filled no practical function: he did not draw with ink. Instead this seems to be a metaphoric use of a tool: the familiar feel of the reed pen in the hand triggered the memory of familiar gestures, transferring a long-established skill into an unorthodox context.

The science of art: Technical examination of paintings by Adriaen van der Werff

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Adriaen van der Werff (1659-1722) was, without any doubt, the most important Dutch master of the late seventeenth century. His classicist paintings, often marked by a biblical or mythological eroticism, and executed in a perfect technique, gained him a European reputation and an enormous fortune. Frederick the Great of Prussia owned at least 20 of his paintings; King Louis XVI of France had 6 of them. Houbraken considered him the greatest of the Dutch painters and this opinion prevailed throughout the eighteenth century.¹

His paintings have never been the subject of technical examinations. Observations on technique, obtained with scientific methods and pieced together with documentary evidence on historic technologies, workshop practices, apothecary lists and studio notes may generate useful hypotheses of artistic intention and development. This may particularly be true in the case of Adriaen van der Werff. His smooth manner of painting, showing hardly any impasto or brush marks and almost imperceptible transitions of colour and tonality, was generally accepted as the standard to follow. Especially in the execution of his soft and silky flesh tones.

In the Rotterdam municipal archive, documents of Van der Werff's colourman are kept that give insight into the pigments that Van der Werff could have had on his palette to accomplish those skin tones. Those data provide a sound basis for the physical and chemical analyses of the materials on his actual palette.

The Rijksmuseum's Print room holds a very interesting correspondence between Van der Werff's assistant Hendrik van Limborch and the scholar Lambert ten Kate. In this correspondence they tried to lay the foundations for a mathematical, 'wiskonstige', quantifiable method of painting.² In their attempt to come to a scientific methodology for the art of painting they relied heavily on Adriaen van der Werff's comments and advice. In these notes we find elaborate descriptions on the quantities and ratios of paints and paint mixtures that Van der Werff used to accomplish his impeccably smooth and downy flesh tones. These notes provide a sound basis for comparison with results of scientific examination.

The objects under investigation were first examined with the stereo-microscope. Based on careful observations a small number of paint samples were taken to investigate the

⁵ Wheelock, A. K., 'Vermeer of Delft: His Life and His Artistry,' in Johannes Vermeer (1995) 162.

¹ Houbraken, A., *De groote schouburgh der Nederlantsche konstschilders en schilderessen*, 3 vols., Amsterdam, 1718-1721.

² Miedema, H., *Denkbeeldig schoon: Lambert ten Kates opvattingen over beeldende kunst*, vol. I, Leiden (2006).

stratigraphy of the paint layers. The samples are analyzed with microscopic, spectrometric, and chromatographic methods to identify inorganic pigments, organic colorants and binding medium. These results of analysis could be evaluated in relation to the contemporary correspondence.

Thus we seek to focus on important developments in painting techniques of the late seventeenth-, and early eighteenth centuries: various preparatory working procedures, the use of intermediate layers and specific methods of the final working-up.

Aspects of Christen Købke's painting technique: From drawing via oil sketch to the final painting

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The focus of this paper is Christen Købke (1783-1853), a leading Danish Golden Age artist from the first generation after the 'father of Danish painting', C.W. Eckersberg. In the first years of his short career in the early 1830s Købke painted small unpretentious and elaborate paintings from the vicinity of Copenhagen in the open air, often seen from oblique angles, as well as intriguing views of Danish Royal Castle roof-tops.

In the mid 1830s he started working on a larger scale, and in this connection he introduced the painted preliminary oil sketch to his oeuvre. He now began composing the subjects, adding details to the observed views and executing drawn detail studies. In parallel with these efforts he still painted a number of small unpretentious views from the surroundings of Copenhagen.

Like many other Danish nineteenth-century artists, Købke also travelled to Italy (1838-40), where he only made a short stop in Rome and spent most of the stay in Naples and Capri. During this stay he worked purposefully to gather preparatory oil studies and compositional drawings as well as drawn detail studies, which were meant for larger compositions that he planned to execute at home in Denmark. He also painted oil studies that were probably not meant for later reworking into larger paintings. From a painterly point of view Købke's brushwork became freer and in several cases more sketch like than was customary in Danish painting of the time.

Back in Denmark Købke's work evolved along two paths; one was the large compositions of Italian views, the other was new small modest studies from the countryside just outside the city.

The paper discusses to what extent Købke followed the initial sketch in the final work. Examples of added or manipulated objects or views in the final image compared to the drawn sketch are presented. Infrared imaging of the paintings reveals that the artist produced underdrawings prior to applying the paint. The underdrawings in certain aspects differ from the initial sketch – an eventual oil sketch - and also from the final painted image - thus offering us a unique insight into the artistic deliberations during the creative process.

The drawings, most of which are kept in the Statens Museum for Kunst, have in some cases been squared before the transfer to the canvas. How carefully the artist would copy the details from the drawing onto the painting, would depend not only on his artistic filtering of marring aesthetic elements but also on how carefully he actually made the transfer. This paper thus offers unique insights into Købke's deliberations during his creative process.

Two 'mechanical' oil paintings after de Louthembourg: History and technique

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Two oil paintings in the collection of the Department of Prints and Drawings at the British Museum are catalogued as mechanical paintings on canvas by Francis Eginton after Philip James de Louthembourg. While the name of de Louthembourg is familiar, that of Eginton is less so. In the period between 1776 and 1782, Eginton, a glass painter and printmaker, participated in a short-lived partnership with Matthew Boulton, the entrepreneurial owner of the Soho Manufactory in Birmingham, to sell mechanical copies of paintings by prominent late eighteenth century artists, including, Angelica Kaufmann, Reynolds, Wright of Derby and de Louthembourg.

The two mechanical copies in the British Museum (BM 1982,0619.1 and 2) are reproductions of original oil paintings portraying 'Summer' and 'Winter' that were exhibited by de Louthembourg at the Royal Academy in 1775 and 1776 respectively. Several other versions of these depictions of summer and winter scenes survive in public collections in the UK; Birmingham Museums and Art Gallery holds two copies of Summer and one of Winter, Brodsworth Hall in Yorkshire has a copy of each composition and the National Portrait Gallery in London a copy of Summer.

Relatively little is known about the precise process by which such mechanical paintings – sometimes referred to as polygraphs – were produced. To date, attempts to understand their method of manufacture, notably the thorough study by Robinson and Thompson,¹ have been based on an analysis of correspondence between Eginton, Boulton and others in their circle and on surviving unfinished mechanical paintings. These unfinished paintings suggest that, as might be expected in view of Eginton's involvement in their production, some type of print was first made based on the original painting and that this was then adhered to a canvas before the oil paint layers were applied, a theory supported by the contemporary records and correspondence.

This contribution approaches the question of the technique used to produce these paintings through a technical examination of the two British Museum copies and the versions held in other collections. Three versions of each composition were imaged in the visible, infrared and ultraviolet regions. Comparison of details from the images revealed which parts of each copy were common to the 'set' and which were the result of hand finishing. Infrared

¹ Robinson, E., and Thompson, K.R., 'Matthew Boulton's Mechanical Paintings', *The Burlington Magazine* 112 (August 1970) 497–507.

reflectography was used to look for evidence of the underlying print on which the finished painting might have been based. In addition, the layer structure of the support and paint was investigated by examining cross-sections, and the paint medium identified by gas chromatography–mass spectrometry.

The results from technical analysis are compared with the evidence available from existing documentary sources, the unfinished paintings and new information kindly supplied by colleagues working on the Soho archives.

The discovery of an early conversation piece by Thomas Gainsborough

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This is a study of Gainsborough's *Coastal Scene with Shipping, Figure and Cottage*, a painting with a full provenance since being acquired directly from Gainsborough in Suffolk. Technical examination revealed three distinct phases of painting. The x-radiograph and the infra-red reflectogram show two portrait figures seated on the left of the wide estuary that is still visible in the right half of the painting. The portrait figures are now hidden by foliage, a cottage and a distant figure. By holding the x-radiograph upside down, one can see the sky of a yet earlier painting, a landscape which was left unfinished.

Using technical examination, art historical evidence, contemporary documents and analysis of the paint, we have evaluated the three phases, throwing light on their date and authorship, and on Gainsborough's studio practice in this period. Circumstantial evidence has led also to discussion of artists restoring pictures in the late eighteenth century, and of questions relating to the formation of lead soap aggregates.

- The first, unfinished landscape is a version of a Gainsborough landscape now in the National Gallery of Scotland. The x-ray of the *Coastal Scene* matched the NGS painting exactly. Technical evidence suggested the *Coastal Scene* is a bit later in date. Documentary sources were used to evaluate Gainsborough's practice in his Suffolk years.
- Analysis of technique, style and costume placed the half-hidden conversation piece around 1748. This highly finished, double portrait in a marine landscape was of very high quality.
- Technical analysis of the pigments in the paint now hiding the portrait figures revealed a palette that could date from the 1780s (Scheele's green) to the introduction of machine-made paint. The absence of any chromium or other early nineteenth-century pigments suggested earlier rather than later. Stylistic analysis of the brushwork ruled out autograph work by Gainsborough (died 1788) but suggested strongly the hand of Thomas Barker of Bath (1769-1847), who was known for his landscapes in the manner of Gainsborough.
- Microscopic examination and cross-sections revealed the reason for this repainting: the hidden composition is densely peppered with microscopic paint losses from the formation of lead soap aggregates within the paint layers. The damaged areas relate directly to the sky of the first, unfinished landscape, which lies principally and most thickly beneath the portrait figures.

- Evidence combines to suggest that the painting was sent for 'restoration' in the late eighteenth century to compensate for this internal damage disfiguring the portraits. The owning family lived in London as well as Suffolk. Thomas Barker was based in London from 1793 to 1800. It is documented that the Barker family of painters restored paintings in their native Bath. There is documentary evidence that other British eighteenth-century painters restored pictures on a regular basis.

'I Can See No Vermilion in Flesh' Sir Joshua Reynolds's portraits of *Francis Beckford* and *Suzanna Beckford* and his painting practice c.1755-6

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In 2008, Sir Joshua Reynolds's pair of half-length portraits, *Francis Beckford* and his wife *Suzanna Beckford*, were studied and conserved at the Tate Gallery as part of the John Schaeffer Nevill Keating Conservation Project. Painted in 1755-6, the portraits represent an interesting period in the development of Reynolds's painting practice. After his return from Italy in 1753, he soon abandoned the traditional technique he had learned during his apprenticeship with Thomas Hudson, and instead introduced daring technical experimentation in an attempt to achieve the grand painterly effects he had so admired in Italian sixteenth- and seventeenth-century painting.

This project has involved the co-operation of conservators, conservation scientists and art historians. Technical examination of the paintings comprised stereo-microscopy, X-radiography and infrared reflectography. Pigments were analysed using polarised light microscopy, SEM-EDX and Raman spectroscopy and media were identified using DTMS with both electron and chemical ionization. Paint cross-section samples were studied using UV fluorescence microscopy, high resolution SEM and FTIR imaging.

This technical examination and paint analysis revealed traditional and innovative methods and materials in both paintings. In the paper these features are illustrated and discussed in relation to other paintings by Reynolds and also with contemporary sources, especially the comments made by Reynolds's pupils and friends. An old paint loss in *Francis Beckford's* cheek provided an unusual opportunity to take a cross-section sample from a face. The evidence so produced has thrown new light on Reynolds's methods for face painting.

Other areas of interest were the pentimenti in both portraits; Reynolds's possible use of professional drapery painters and assistants for background and costume; the effects of time, restoration and the artist's technique on the paint layers, and the consequential changes in perception of the portraits, particularly the characteristic deterioration of the faces. The role and limitations of paint analysis in making cleaning decisions is discussed, particularly when dealing with partial and disrupted layers.

Cadmium yellow in *The Scream* painted by Edvard Munch

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There are two painted versions of *The Scream*. One belongs to the National Museum of Art, Architecture and Design (former National Gallery, referred to as 'NG Scream'). It is signed and dated 1893. The other version belongs to the City of Oslo (Munch Museum, referred to as 'MM Scream'). It is not signed or dated, but datable to 1910(?). Both versions are well known and considered major works of the respective collections.

The paper will include two aspects.

1. A survey of Munch's versions of *The Scream*, with special attention to the painting belonging to the Munch Museum. (Biljana Topalova-Casadiego)

The 'MM Scream' was stolen in August 2004. After its return in 2006, the museum conducted an extensive technical examination of the ill-treated and damaged painting, and pigment analyses were made using an XRF non-destructive hand-held instrument. In addition, during 2007 thorough analyses of pigments and media were carried out by Brian Singer, Northumbria University. Prior to the theft, analyses of paint samples were made by Unn Plahter in 1974 and 1992. In 2004, just before the theft, a study of the painting techniques was carried out by Topalova-Casadiego, research work that was continued after the painting's return in 2006.

This presentation will include the main trends of the painting techniques in each of the two painted versions of *The Scream* with an emphasis on how the design layers of paint were applied. Finally the investigation to assess the damages inflicted upon the 'MM Scream' will be discussed.

2. Analyses of the yellow Cd-based pigments. (Unn Plahter)

Analyses have revealed that the pigments used correspond to those found in contemporary art. However, the analyses in 1974 showed that a pale cadmium yellow on the 'MM Scream' contained a large proportion of white cadmium carbonate. Recent analyses using XRF also indicated that grey strokes in the sky of the 'MM Scream' are cadmium based. It seems reasonable to assume that when Munch applied the strokes now observed as grey, they were originally pale yellow and that the yellow hue has since faded. Analyses also suggest that the faded pigment is not produced with the wet method but with a dry method.

This presentation will include some references to technical literature on cadmium yellow. It will discuss production methods for cadmium yellow with special attention to the dry method. A mapping of the distribution of faded cadmium yellow within the pictorial area is based on non-destructive analyses carried out with a hand-held XRF analyser. Finally an effort to visualise the impact of the fading will be attempted using digital photo technology.

Action speaks louder than words – Thomas Couture as a teacher

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This contribution focuses on the teaching practices of the painter, Thomas Couture (1815-79), contextualising his contribution within the seminal changes within academic practice in France in the latter half of the nineteenth century.

As a painter, Couture is best-known for his enormous painting, the *Romans of the Decadence*, now in the Musée d'Orsay, which earned him a gold medal at the Salon of 1846. Although its success assured him a series of major commissions from leading figures in the French cultural and artistic establishment, including the Imperial family, he was unable fully to capitalise on its success, and in his later career turned increasingly to work within the 'minor' genre of portraiture and 'harlequinades'. Despite this, his teaching practice during this same period went from strength to strength, and he developed a formidable international reputation as a teacher. Couture propagated his 'methods' in a number of publications, most significantly his *Méthodes et entretiens d'atelier*, published in 1867, and translated into English by an ex-student in 1879 as *Conversations on Art*. These are idiosyncratic publications, heftily opinionated, verbose and rebarbative, and too often off the point. But as written records of painting techniques, they remain among the most detailed to have survived from the period. Unlike other painters, Couture had no apparent qualms about sharing his stylistic 'secrets' with a wider public, and supplemented his written instruction with a series of rapidly-executed figure studies executed specifically for students as a visual, step-by-step teaching aid. Many such *études de figures* were in his possession at his death; many others destroyed. A remarkable example of one, *Head of a Young Girl*, survives in the Fitzwilliam Museum, Cambridge, and serves as an excellent demonstration of the facility of execution and speed which he encouraged among his students.

Although some of his most gifted students – famously Edouard Manet – would later repudiate his methods, his teaching proved to have international appeal, and students from Scandinavia, Germany and especially America, flocked to his studio, first in Paris, and later in his native town of Senlis. Decades before the Impressionists, Thomas Couture was 'painting quickly' on his own terms, and spawning a generation of students who would follow his example.

A comparative study of Vincent van Gogh's *Bedroom* series

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This paper will present new art historical and technical findings resulting from a broad collaborative study of Vincent Van Gogh's three paintings of his *Bedroom* in Arles, in the collections of the Van Gogh Museum in Amsterdam (de la Faille cat. no. 482¹), The Art Institute of Chicago (F 484), and Musée d'Orsay in Paris (F 483). A comparison of the three versions will focus on changes in the painter's working method and artistic ideas evident across the series, proceeding from the prototype painting made in October 1888, to the same size copy made in the asylum at Saint-Rémy in September 1889, and the smaller copy made for his sister Wil. The question of which painting was made first- the Amsterdam or Chicago version - will be addressed.

The paper will be divided into sections covering the following topics; the art historical background and provenance of the paintings including mention in Van Gogh's correspondence, physical and documentary evidence for early damage and restoration of the Amsterdam and Chicago pictures, characterization of the canvas supports including the creation of digital weave maps to help match up pieces cut from the same roll, analysis of preparatory size and ground layers, the presence of underdrawing, compositional adjustments, characterization of the palettes used, changed appearance due to the deterioration of colours such as faded red lakes, and a comparison of brushwork and paint application techniques.

¹ Faille, J. -B. de la, *L'Oeuvre de Vincent van Gogh: Catalogue raisonné*, Paris/Brussels (1928).
Revised edition: *The Works of Vincent van Gogh: His Paintings and Drawings*, New York, (1970).

Benjamin West and the Venetian secret

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In September 2008 the Yale Center for British Art mounted a small exhibition, *Benjamin West and the Venetian Secret*, which focused on two versions of *Cicero Discovering the Tomb of Archimedes* by Benjamin West, the American-born president of the Royal Academy of Arts. The two versions, one painted in 1797 and one in 1804, show stark differences in colour, texture, and tonality, and the aim of the exhibition was to make art-historical, technical, and scientific sense of the discrepancies.

In 1795 a shadowy figure, Thomas Provis, and his artist daughter Ann Jemina, persuaded Benjamin West that they possessed a copy of an old manuscript describing the materials and recipes used by Venetian painters of the High Renaissance. In fact the manuscript was a fake and the story an absurd invention, but over a two year period the Provises managed to dupe not only West, but also a “syndicate” of Royal Academy members who hoped to advance their careers with the Provis “secrets.” In 1797, when the fraud was exposed, the embarrassment to West and the other artists was acute. Critics derided them in the press, Paul Sandby penned lewd verses for song, and James Gillray published a remarkable hand-coloured satirical engraving that embedded a complete iconography of the episode.

While the Venetian Secret scandal is well-known to art historians,¹ the recipes contained in three surviving versions of the Provis manuscript have never been compared to West’s use of them in his paintings. Five methods of analysis were applied to the two paintings: careful looking; x-radiography, infrared reflectography, microscopy and instrumental analysis. The results showed that in some respects the 1797 picture is consistent with aspects of the Venetian secret manuscripts, but in other ways with standard practices of eighteenth-century painting. In 1804 West set aside what he had gleaned from the Provises in favour of more conservative studio practice.

Technical study strengthened our understanding of the ancient literary subject, *Cicero Discovering the Tomb of Archimedes*. West chose it to demonstrate the benefits of curiosity and knowledge over ignorance and apathy and the painting served as a vehicle for him to introduce what he thought would be the technical discovery of his era. Through close collaboration between conservator, curators and scientists, the research team was able to propose an explanation for West’s return to orthodox methods in 1804, when he created not just a replica of *Cicero* but a kind of “atonement” painting meant to repair his damaged reputation.

¹ Gage, J., ‘Magilphs and Mysteries’, in *Color and Meaning: Art, Science and Symbolism* (1999) 153–161.

James McNeill Whistler; fluidity, finish and accident

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Anecdotes talk about Whistler's use of strongly diluted paint, his 'sauce', composed according to his assistant Greaves, of copal and mastic resins and turpentine, which Whistler applied to horizontally placed supports to avoid dripping and bleeding. In every study of Whistler's paintings, this anecdote occurs, but analysis of the possible use of this technique focused on his nocturnes, where the flowing character of the paint seems to fit the anecdotal description well. Scientific analyses of several nocturnes and of palette paints (Tate Britain, Hunterian Art Gallery) showed the presence of mastic resin, lead drier, and stand-oil as a possible composition of Whistler's 'sauce', while no copal was identified (Townsend, Hackney, 1994-1995).

Whistler's own statement: 'A picture is finished when all trace of the means used to bring about the end has disappeared' is often connected to the 'sauce', as its fluidity would obliterate any trace of the brush. Interestingly, brushstrokes are clearly visible in most of the early nocturnes where they are actually used as a compositional device. They become difficult to discern in the nocturnes and oil portraits from the late 1870s - early 1880s. In the portraits the fluidity of the paint is clearly visible in the areas of dripping, which have not been rubbed or painted out. This has often led to the assumption that these works are in a non-finished state. However, some were signed, exhibited and sold by Whistler, which suggests otherwise.

Whistler employed or manipulated 'accidental' effects in his works in other media, such as in his use of acid in etching copper plates. Leaving such effects and 'drip' marks may have been developed by the artist during the 1870s, in order to accentuate a vivid, spontaneous freshness.

During UV examination of *Arrangement in Yellow and Grey: Effie Deans* (1876-78, Rijksmuseum) unexpected variety in strength and colour of fluorescence was noted that seemed connected to the thin paint applications, the latter sometimes hardly visible to the naked eye, which makes varnish removal highly risky. Similar use of runny, highly transparent paint can be observed in three full length portraits of Milly Finch (c. 1885, Hunterian Art Gallery). Interestingly a similar phenomenon was observed in *Portrait of Mlle Eva Callimaki Cartagi* by Henri Fantin-Latour (1881, Kröller-Muller Museum). Whistler and Fantin were close friends and a mutual influence is therefore plausible.

To obtain a true understanding of the layer build up and paint, or 'sauce', composition, samples of the mentioned works are examined using more conventional techniques such as light microscopy with staining tests, FTIR microscopy, gas chromatography with mass spectrometry. Furthermore, we will investigate the suitability of alternative novel high-resolution, spectrally-resolved brightfield microscopy and single-photon and multi-photon optical sectioning imaging methods to detect the presence of natural resins and different media in the paint layers, and to provide the necessary resolution for the precise separation of different layers, including 'real' varnish layers. Similarly samples from Fantin-Latour's portrait are examined. Results are combined with documentary evidence from the Whistler correspondence, including that between Fantin and Whistler (University of Glasgow), to arrive at a clear evaluation of the role of Whistler's 'sauce' for the fluidity, finish and accident in his later works.

POSTERS

Surface condition and chemical reactivity of paints, related to the technique and former treatments of *The Tribute Money* by Jacob Jordaens

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Jacob Jordaens's early masterpiece *The Tribute Money, Peter finding the Silver Coin in the Mouth of the Fish*, also called *The Ferry Boat from Antwerp* (c.1623) [Inv nr. KMS 3198] was restored in the Statens Museum for Kunst in Copenhagen between 2007-2008.¹ The removal of the yellowed varnish layers revealed a paint surface which was locally extremely affected by metal soap protrusions. The differences in the levels of saponification of the paint layers seemed to be related to differences in date and technique in the 8 different pieces of canvas of which the painting is composed and to specific pigment areas. The cleaning of the blue paint layers of the sky was furthermore complicated by metal soap related degradation and formation of aggregates in the surface. Research was undertaken with chemical microscopy to determine the composition of the aggregates, the degree of chemical reactivity below the surface and to evaluate the stability of the paints.

Discoveries

In a cross-section from 1969 a large aggregate in the ground layer of the painting, a mixture of chalk and some earth pigments in drying oil, could now be recognized as a lead soap aggregate thanks to the recent developments in the understanding of the phenomenon.² The sample originated from one of the two oldest canvases - now found to be mostly affected by lead soaps breaking through the surface - on which Jordaens started the composition.³ A new sample taken where a hidden protrusion had distorted the surface showed once more that a large soap mass surrounded by minium crystals had formed at the bottom of the first ground layer. Saponification had affected lead white containing paint layers above the ground considering their degraded condition. Microscopic examination of the surface also revealed the orange colour of minium at the surface in the more affected areas. These phenomena point to mobilization of lead soaps towards the reverse and crystallisation at distance from the upper layer source of these soaps. The painting has a long history of structural treatments and restoration⁴ and it is possible that a starch paste lining of the painting in the past has been the catalyst of the metal soap mobilization process. The lead soap aggregates are in variable stages of remineralisation

¹ Filtenborg, T., Hendrikman, L., Noldus, B., De la Fuente Pedersen, E., Schlotter, A., Verhave, J., and Wadum, J., *Jordaens the making of a master piece*, Statens Museum for Kunst, Copenhagen (2008).

² Keune, K., and Boon, J.J., 'Analytical imaging studies of cross-sections of paintings affected by lead soap aggregate formation', *Studies in Conservation* 52 (2007) 161-176.

³ Verhave, J., Schlotter, A., and Filtenborg, T., 'Jordaens at work, layer upon layer', in: Filtenborg et al opus citatis 1. 69-93.

⁴ Filtenborg, T., 'The treatment history and recent restoration', in: Filtenborg et al opus citatis 1. 55-69.

pointing to partial stabilization of the process. Further evidence for mobilization of metal soaps was found throughout the painting in the pale blue smalt paint layers of the sky. Thousands of whitish 100 micron wide lumps are covering the surface, which after varnish removal leave remnants of a soft white material. These lumps consist of lead potassium sulphates as shown by SEM-EDX, FTIR and Raman imaging. These same compounds are also present, although more dispersed, in layers near the surface. Lead white between the smalt has partly reacted away and new mineralization containing lead is appearing in electron transparent metal soap containing areas. The smalt lead white paint is presently very poorly bound and brittle requiring ion polishing⁵ to obtain a readable cross section. The potassium has almost completely migrated away from the smalt particles and reacted with the lead soaps and fatty acids in the paint. Some larger lead white particles show lacunae where crystal matter has reacted away. Metal soaps accumulating on the contact of the smalt paint and the lead white underpaint created a mechanically weak zone full of open spaces in cross-section.

Comment

Jordaens's way of stitching several parts together, transforming existing paintings into new works, and overpainting already dried paint are thought to have precreated conditions that were prone to mobilizing metal soaps later on. Oil from the overpainted areas of *The Tribute Money* must have enriched the lower already partially aged paint thus leading to a potential reservoir of reactive fatty acids.⁶ In addition, the painting has been subjected to a number of different conservation treatments over the centuries with unknown consequences for the internal chemical condition of the painting. The appearance of lead soaps at the contact of canvas and ground, and the presence of protrusion craters and large aggregates of potassiumlead sulphate presumably formed via potassium and lead soap at the surface suggest complex mobilization patterns along internal channels in the paint multilayer system. A detailed study of these mobilization patterns will benefit the material future of the painting. Evidence from our study demonstrates that the metal soap mobilization processes are still continuing.

⁵ Boon, J. J., and Van der Horst, J., 'Remarkably improved spatial resolution in SEM images of paint cross sections after argon ion polishing', in *Preparation for painting*, J.H.Townsend, T.Doherty, G.Heidenreich and J.Ridge (eds), Archetype Publications, London (2008) 42-50.

⁶ Boon, J.J., Hoogland, F., and Keune, K., 'Chemical processes in aged oil paints affecting metal soap migration and aggregation', in *AIC paintings specialty group Postprints Volume 19*, Helen Mar Parkin Compiler, The American Institute for Conservation of Historic and Artistic Works, Washington (2007) 16-24.

Investigating a reconstructed altarpiece by the Master of the Fogg Pietà /Maestro di Figline

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Initial results of a project that integrates art-historical and technical information gathered from a group of related but dispersed works by the Master of the Fogg Pietà (also known as the Maestro di Figline), a major but little-studied artist, active in Florence and Assisi, c.1310–1330, will be presented. The reconstruction of the polyptych, initiated by Richard Offner, amplified by Carlo Volpe, and refined by Miklos Boskovits, Norman Muller, and Dillian Gordon, comprises the artist's name panel, the Pietà,^b and works in London^a (St. Lawrence; Bishop Saint); Avignon (Musée du Petit Palais: God the Father); Parma (Magnani-Rocca Foundation: Saint John the Baptist); Rome (Private Collections: Saint Peter, Saint James Major, Saint Cosmas or Damian (?); Bishop Saint); 's Heerenberg (C. J. H. Van Heek Collection: Saint Paul and Saint Lucy); and Worcester, MA (Saint Francis and Saint Philip)^c.

The project, funded by the Andrew W. Mellon Foundation scheme for conservation documentation, is coordinated by the Courtauld in partnership with other institutions and museums.^{b-e} An online tool has been created for collaborative research that enables the partners to share and exchange technical, archival and art-historical information via an interactive web-site.¹ The project endeavours to emulate the experience of gathering the relevant paintings, and the conservators and curators who study them in the same virtual space. Materials online include new high resolution images (IR, visible and X-radiographs); selected analysis of pigments, cross-sections and binding media; as well as conservation documentation, information from previous technical studies, and archival photographs.

In addition to the reconsideration of a reconstructed altarpiece, the web site facilitates the investigation of the Master's working practice within, and beyond, the panels of this group. These include his other name panel, the Virgin and Child Enthroned with Saints in the Collegiata of Figline Val d'Arno, and his crucifix in S. Croce, Florence. The Master's few surviving paintings demonstrate his connections with Umbria and Florence, and his imitation of certain Sieneese decorative techniques. In addition, his work also exhibits several curious technical characteristics, including geometrical planning for cusped framing; preparatory white outlining around the edges of figures; use of a green composed of

¹ www.mfpmfp.org

malachite, ultramarine and lead white glazed with copper resinate; surface modelling of flesh with carbon black and yellow glazes, and, most notably, the omission of terra verde from flesh painting. Preliminary findings of this collaborative research project will be presented, and the way the collaborative web-based project functions will be demonstrated, highlighting how the international group of scholars that it brings together is building on previous work, and is reassessing the form and context of the Master's polyptych.

3D Synchrotron X-ray tomographic microscopy of paint samples

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The first volume of the National Gallery Technical Bulletin, published in 1977, contains three articles on scientific research of artists' materials, anticipating the importance that such activity has had for an improved understanding and care of works of art.

The bulk analysis of single paint layers gives important information towards the composition and the condition of artists' paints. The surface chemical study of cross sections has brought new insight into artists' paint chemistry increasing our knowledge of paint reactivity and artists' technique.^{1,2} It has shown that paint is a chemically and physically dynamic system, continuing to change long after the picture is complete and sensitive to environmental factors. It has also helped understand the condition and appearance of many paintings. However studying only one plane of the paint sample has limitations.

Synchrotron based X-ray tomographic microscopy is a novel way to examine paint cross sections. Instead of embedding, grinding and polishing, the paint sample is not sectioned at all but studied in a computer environment which reconstructs the three dimensional distribution of the pigment particles, media and other features. Experiments on paint chips (approximately 500 micron wide) were done on the TOMCAT beam line (TOmographic Microscopy and Coherent rAdiology experimenTs)^{3,4} at the Paul Scherrer Institute in Villigen, CH, using an X-ray energy of up to 38 keV. The resolution of the reconstructed X-ray absorption images is 350 nm and the large data cubes obtained consisted of up to 2048 tiff images of 1024 x 1024 pixels. The data were analysed using the commercial 3D imaging software Avizo 5.1.

The potential of this technique has been explored in the context of the study of the early works of Cuno Amiet (1868-1961), one of the most important Swiss painters of classical

¹ Boon, J.J., 'Processes inside paintings that affect the picture: chemical changes at, near and underneath the paint surface' in *Reporting Highlights of the De Mayerne Programme* Boon J.J., and Ferreira, E.S.B. (Eds), NWO publishers (2006) 21-32.

² Ferreira, E.S.B., Morrison, R., Keune, K., Boon, J.J., 'Chemical Characterisation of thin intermediate layers: Case study of a sample from the 15th century painting the Descent from the Cross by Rogier van der Weyden' in *Reporting Highlights of the De Mayerne Programme* Boon J.J., and Ferreira, E.S.B. (Eds), NWO publishers (2006) 53-62.

³ Stampanoni, M., Borchert, G., Wyss, P., Abela R., Patterson, B., Hunt, S., Vermeulen, D., and Rügsegger, P., 'High resolution X-ray detector for synchrotron-based microtomography', *Nuclear Instruments & Methods in Physics Research Section A* 491 (2002) 291-301.

⁴ Stampanoni, M., Groso, A., Isenegger, A., Mikuljan G., Chen, Q., Bertrand, A., Henein, S., Betemps, R., Frommherz, U., Boehler, P., Meister, D., Lange, M., and Abela R., 'Trends in synchrotron-based tomographic imaging: the SLS experience', in *Developments in X-Ray Tomography Proceedings of SPIE* volume 63180M (2006) Bonse, U. (Ed).

modernism, currently the focus of research at the SIK-ISEA. This technique gives access to unique information such as sample surface morphology, particle size distribution throughout the whole sample, the porosity level and the link between inner layer properties and surface appearance.

One further elegant feature of this technique is that a target section, selected within the 3D data set, can be exposed to obtain chemical data on a selected location. The X-ray absorption information observed in the virtual section can then be compared with the chemical information obtained from the selected cross section made in the traditional way. The potential of this novel approach will be demonstrated with selected examples.

Materials used on the ground layers of sixteenth- and seventeenth-century Spanish paintings

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The ground layer applied over the support is a key step in the process of a painting. Firstly because the painters need to work on a uniform and very little absorbent surface and secondly, because they require an adequate coloured base to make the work. These two necessary conditions for good practise imply a careful and deliberate selection of materials, so the study of these layers can offer useful information for painting technical documentation, related to the way the artists work and about the purchase sources of materials.

The study's results about the colour and composition of the ground layers in a group of paintings by Spanish masters of the sixteenth and seventeenth centuries are presented here. The results include a general identification of pigments and any other inorganic compounds used in ground and priming layers, analyzed by means of SEM-EDX, as well as binding media and organic ingredients that were added to the mixture, analyzed by GC-MS. The aim of the present study is to establish a relationship between the selected materials in the ground layers, the type of support, the painters' school and also the moment and location where the painting was made. This research offers important preliminary information about the techniques and materials used by the Spanish painters that will be systematically increased with the analysis of other paintings from the Prado Museum collection.

The painters whose works have been studied are: Juan de Flandes, Pedro de Campaña, Blas de Prado, Juan Pantoja de la Cruz, El Greco, Vicente Carducho, Fray Juan Bautista Maino, Francisco Ribalta, José Ribera, Pedro Núñez del Valle and Bartolomé Esteban Murillo all of them working in the period from 1509 to 1678.

The Raphael research resource:
<http://cima.ng-london.org.uk/documentation>

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Since 2007, the Andrew W. Mellon Foundation has been funding a series of pilot projects in digital recording and transmission of conservation documentation (<http://mac.mellon.org/issues-in-conservation-documentation/pilot-projects>).

The National Gallery's *Mellon Digital Documentation Project* has been centered on the Gallery's remarkable and diverse group of ten paintings by Raphael because – as a result both of long-term research and of recent reassessment arising from the exhibition held in London in 2004/5 – there is extensive primary material on Raphael, much of it already interpreted in various publications. The outstanding documentation on Raphael, kept across the National Gallery's departments and archives is currently available only internally and to visiting scholars. For the first time, this valuable resource, compiled over nearly 200 years since the National Gallery's foundation in 1824, will be made available digitally as part of the gallery's website for both specialists and the general public. Further research and new results obtained after the Raphael exhibition in 2004/5 will also be made available and published online for the *Mellon Digital Documentation Project*.

The collaboration with other institutions (currently the National Galleries of Scotland, Edinburgh, the Metropolitan Museum of Art, New York and the C2RMF, Paris) will allow for the inclusion of other works by Raphael, bringing together art-historical, technical and conservation-based information and creating a platform which could eventually host Raphael's complete oeuvre in unprecedented depth. This pilot project addresses a primary challenge for the museum community: the formulation of a coordinated effort to create and share new digital content and to make it available for researchers and the general public. The *Mellon Digital Documentation Project* explores new ways of recording and sharing information and hopes to establish a high-profile standard for documenting and presenting artworks in the twenty-first century.

Microcissing; a form of drying crackle in British eighteenth-century oil paintings

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In 1990 a paper was published describing microscopic drying cracks which can seriously distort the appearance of the paintings they occur in (Rica Jones: 'Drying crackle in early and mid eighteenth-century British painting', in *Appearance, Opinion, Change: Evaluating the Look of Paintings*, UKIC, 1990, pp.50-52). More than half of British paintings from the early part of the eighteenth century till the 1760s suffer from this phenomenon to some degree but some are completely broken up with this microscopic system of cracks, craters or 'islands' of paint. Hogarth's conversation pieces of the 1730s and 40s are particularly badly affected.

In the years since 1990 more examples have been found. While microcissing can be seen occasionally in continental paintings from the seventeenth and eighteenth centuries, it remains principally a problem of British art. This poster illustrates the problem and seeks to elucidate the phenomenon, drawing on information from the following areas: scientific analysis of specific paintings, especially of their binding media; microscopic examination of paint samples; published information on the drying of paint from the paint manufacturing industry; contemporary references to artists' practice; contemporary manuals of painting.

Between easel and wall painting? Albrecht Altdorfer's painting fragments of the Regensburg Bishop's Court

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Since the essay by Smith and Wyld in the 1983 volume of the NGL Technical Bulletin¹ surprisingly little has been published on the painting technique and materials of the Regensburg painter, illustrator and master-builder Albrecht Altdorfer. A recent conservation treatment on Altdorfer's wall painting fragments at the *Historisches Museum Regensburg* - one-of-a-kind in the oeuvre of the artist - initiated technical and scientific studies revealing many similarities to his working practice on wooden panels.

Around the year 1535, Albrecht Altdorfer decorated the walls of the private rooms of the Episcopal administrator *Johann III, Pfalzgraf bei Rhein* with amorous bathing scenes. The paintings were only rediscovered in 1887, after the covering whitewash layers had detached due to a fire that devastated parts of the bishop's court. Before the building was pulled down, 22 fragments of Altdorfer's paintings, mainly figurative scenes, were removed from the wall by the *stacco* technique. The fragments were restored in 1938, arranged in groups and fixed in plaster beds. Embrittlement of glue remnants on the surface lead to gradual paint layer detachments and made new conservation measures necessary.

The technical study as well as material analyses of pigments and binding media, yielded new insights into Altdorfer's technique, be it his approach to the unfamiliar medium of wall painting or managing the unusually large format. Altdorfer started his work by grounding an old lime plaster with an egg-bound chalk layer, but without evening the plaster's defects. He transferred the composition from a squared preparatory drawing (today in Florence) by incising a grid. Infrared reflectography revealed a spontaneously executed underdrawing of the figures carried out in soot paint. The paint application generally varies in pastosity and visibility of the ductus, e.g. traces of brush stippling and finger wipes were observed. The softly-modelled carnation with remnants of thin glazes is visibly smoother than other parts. The appearance and stratigraphy of the paint layers and especially the use of translucent glazes, e.g. in the green and red robes, resemble an easel painting executed in oil. Delicate details such as strands of hair were applied in a less wetting medium.

¹ Smith, A., and Wyld, M., 'Altdorfer's Christ taking Leave of His Mother', *National Gallery Technical Bulletin* 7 (1983) 51-64.

Gas chromatography–mass spectrometry and amino acid analyses identified egg and boiled drying oil (probably linseed oil) as the medium of the paint layers – in a mixture to be denoted as “fat tempera”. Altdorfer obviously intended to obtain the optical impression of an oil painting, although he must have known that this material could be problematic on a wall. He therefore based his binding media on egg tempera, and added as much oil as he needed for the respective pigment or optical effect.

SEM–EDX analyses detected common inorganic pigments but also less lime-proof organic red, yellow and brown colorants. Two mineral pigments deserve special discussion: The analyses confirmed again that Altdorfer used fluorspar as a pale purplish pigment – a mineral available in close proximity to Regensburg in the Nabburg / Wölsendorf district. Furthermore, a Mountain Green pigment contained an elemental pattern regarded as typical for copper minerals of the Schwaz / Brixlegg region in Tyrol.

Contribution to the digital image processing systems in the technical study of complex Old Master paintings

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The goal of this paper is to show the results of several studies performed in the Museo Nacional del Prado on a number of easel paintings (with special attention to Andrea del Sarto and Joachim Patinir) using high resolution digital images. The use of this technique has proved essential for the development of research projects in the conservation field, either as a research tool or as a means of showing the conclusions of a study in the most appropriate way.

With these analyses, we intend to obtain a more empirical vision on how the paintings were made as well as on their state of conservation, taking into consideration that when observing a painting, what we see depends on the interaction of the surface with the internal layers and the support. This visualization is at the same time conditioned by the age of the work of art, the restorations it has undergone and its material history.

In this context, the high resolution digital image processing has been incorporated as a method for interpreting the graphic information generated by different technical studies (infrared reflectography, X-radiography, ultraviolet fluorescence, macro-photography) which adequately complement the historical documentation. Just as these analyses allow us to see more than we are able with the human eye, the digital images help us discover hidden data that usually cannot be perceived without these tools.

These analysis procedures have been integrated into the Museum’s daily research activities, but always bearing in mind that the digital images are only tools and not a goal by themselves. The results that can be obtained depend on the data reliability, the correct specification of the theories that we aim to demonstrate or the preliminary problems to be solved and the processing and interpreting of the correctly gathered data.

All that's burnished isn't bole (nor from Armenia)

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This poster examines the use of 'bole' before 1600; while this substance is familiar to all scholars of painting technique, its history and very identity are poorly defined in the technical literature.¹ Herein, the use of 'bole' by European painters, from the time of its introduction in the mid-thirteenth century to c. 1600, is considered in light of evidence derived from the analysis of surviving paintings and study of documentary sources.

Information pertaining to the use of bole, both in the form of modern analysis and from contemporary documents, is remarkably sparse. There has been a tendency to automatically categorize any red material lying directly under a layer of metal leaf (or even under layers of paint) as 'bole', often without the benefit of analysis. Neither have burnished gilding grounds, or 'poliments' (to borrow from the German technical vocabulary), whose colour deviates from the expected reddish hues been analysed with any frequency. They have often been classified simply by appending their observed colour to their supposed composition: so-called 'boles' in green, brown, black, purple, yellow and white tones. The extant analyses tend to be isolated instances rather than elements of larger programs of systematic research. Thus, it is necessary to consider a wider cross-section in order to obtain an impression of earlier practice. Study of the extant results reveals that considerable variation in the composition of poliments was typical in certain regions, especially north of the Alps.

This circumstance is somewhat unexpected as the practice of gilding has long been represented (for example, by classic texts such as D.V. Thompson's *The Materials and Techniques of Medieval Painting*) to have been in conformity with the materials and processes described by Cennino Cennini: gilding on a preparation consisting of an aqueous binder and red, clay-rich material, 'Armenian bole' (*bolio armenico*). The variance found in the technical literature is, however, supported by a closer examination of the contemporary sources, which are surprisingly few in number. Within the surviving recipes for gilding on panel, the use of bole is not consistently cited, nor in many cases is it listed as the main ingredient. Equally, a range of other materials are frequently given as potential substitutes.

What then, did the appellation 'Armenian bole' suggest to the contemporary painter? Consideration of evidence for the prices for boles and related materials found in purchase documents and *taxae* suggest that a certain physical quality, rather than a specific material imported from far-off Armenia was understood. It is also suggested that the rather confusing use of term 'bole' to designate the entire mixture, rather than simply the substance, was a later development, at least in the north of Europe.

¹ This paper continues the topic broached in an earlier article by the author: 'All that's Burnished isn't Bole. Reflections on Medieval Water Gilding Part I: Early Medieval to 1300', in *Medieval Painting in Northern Europe. Techniques, Analysis, Art History*, ed. J. Nadolny, Archetype, London (2006) 148-62.

Holbein's blue backgrounds: Meaning, materials and degradation

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A startling number of the blue backgrounds in paintings by Hans Holbein the Younger (1497/98-1543) no longer appear as they were originally intended. That the now dark green, grey or even brown backgrounds were originally blue is made evident by scientific analyses where the blue pigments - azurite or smalt - have been identified. Only in a few cases did Holbein use the extremely costly and more durable pigment, ultramarine (c.1537, *Henry VIII*, Madrid). In many of his later portraits the blue backgrounds are reduced to a single plane of colour where degradation, often coupled with damage as a result of later interventions, makes the spatial relationship of the figure and background difficult to interpret.

Microscopic examination of three paintings in the Royal Picture Gallery Mauritshuis, reveal that all three backgrounds have dramatically changed in appearance. In the *Portrait of Robert Cheseman* (1533, inv. 276), the now dark blue-green patchy background is painted with the mineral pigment azurite, whose hue is determined by its particle size (the coarser the particles the more brilliant the blue). Losses in the inscriptions reveal that the background was originally much brighter. Paint cross-sections demonstrate a single layer of large brilliant blue azurite particles (c. 60 micrometres diameter) with a small amount of lead white, applied over a mid-grey priming on top of a chalk ground. It is notable that the particles are remarkably even in size. Holbein's choice for a coarse grade of azurite must lie with its brilliant colour. Furthermore, the application on top of a dark grey underlayer, in this case the ground, makes the azurite appear darker, an efficient way of creating a deep blue colour with a single paint layer. Here mass spectrometry (DTMS) identified linseed oil as the binding medium of the azurite layer. Brown residues of an oil-resin varnish in many areas of the background were also identified with DTMS as a mixture of linseed oil and a diterpenoid resin, possibly pine resin. It is not known whether this varnish was applied by Holbein himself, or somewhat later to provide saturation and gloss to the coarse-textured blue background which otherwise would have appeared matte. In paint cross-sections it can be seen that this varnish has deeply penetrated the porous paint layer. Although the binding medium of (pure) azurite paint layers have sometimes been reported as having turned brown, here impregnation and darkening of the oil-resin varnish seems to be the major reason for the darkening observed. Subsequent abrasion and overpainting of the background due to removal of this oil-resin varnish in the past, accounts for its now uneven colour and texture.

In Holbein's *Portrait of Man with a Hawk* (1542, inv. 277), the background consists of a mixture of lead white and smalt, a powdered potash glass coloured with cobalt. This is applied over a light grey underpaint on top of a white priming. The colour of smalt is

related to its particle size and the amount of cobalt present. SEM-EDX analyses reveal the use of two qualities of smalt, coarse blue particles and fine colourless-grey particles, both with unusually high arsenic levels. The depletion of potassium has been shown to be associated with the decolourisation of smalt;¹ indeed the low potassium concentrations inside the grey smalt particles indicate that they are almost completely discoloured and accounts for the now grey appearance of the background paint. It is noteworthy that when discoloured smalt is part of a transparent matrix, such as in *Edward Prince of Wales* (1538, Washington)² the blue colour is completely lost demonstrating the influence of the paint matrix and role of the underlayers on colour perception. Degradation of smalt is also possibly the reason for the overpainting of the background in *Portrait of Jane Seymour* (Holbein Studio, c.1540, inv. 278) which now appears dark green. Here several changes have taken place. On top of the salmon pink priming the background was initially painted with smalt. At some point in the past, it was then overpainted with lead white, followed by a layer of azurite, and more recently with a thick brown glaze.

Comparison with related pictures where the backgrounds are well preserved further demonstrates the relationship between materials and degradation. In *Portrait of Jane Seymour* (1536-37, Vienna) a mixture of smalt, lead white and carbon black was identified in the background. Here the application on top of a dark underpaint, along with the possible tempera-binding medium and/or the admixture of lead white in the paint, appears to contribute to the unusually good appearance of the smalt.³ Similarly in *Lady with the Squirrel and Starling* (1526/8, London), which is painted with azurite, the admixture of large amounts of lead white appears to be the reason why its bright blue colour appears/is so well preserved.⁴

Clearly, changes in appearance not only result from the material properties of the different blues, but also from the way in which the pigments were used: the use of varnishes, the other pigments in the paint layer, the binding media, along with the colour of the underlying layers and grounds. All these factors play a significant role in our perception of colour and the degradation phenomena they exhibit.

The use of ground siccative glass in Spanish Golden Age priming layers

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The detection and identification of ground siccative glass particles, as part of the priming layers on seventeenth-century easel painting, was undertaken within the context of comprehensive research into the technical aspects of Spanish Golden Age still-life paintings. The difficulty in detecting particles of this nature in layered sections by means of optical microscopy means that alternative analytical processes are required, such as scanning electron microscopy (SEM-EDX). This research characterised sodium-calcium, potassium, and high lead content glass, as well as the more commonly present cobalt-containing smalt. The results obtained have been matched with documentary sources and the scant references available in the treatises of the time, which almost always refer to siccatives for certain types of pigments in paint layers and, only in a general manner, to their addition to ground layers. Accordingly, only the treatise by Felipe Nunes (published in Lisbon in 1615) *Arte poetica, e da pintura e symetria, com principios da perspectiva* recommends the addition of siccatives such as ground glass to the priming layer. It is interesting to consider the reason for the addition of these accelerators towards the end of the seventeenth century, especially in Madrid; they are associated, above all, with the extraordinary commercial output of pre-prepared fabric supports for supplying the numerous artists active in the Court at those latter stages of the century. Specifically, we have noted the presence of these glass siccatives in paintings by Gabriel de la Corte; in the case of a *Vanitas* by Antonio de Pereda smalt was identified in a curious brown priming layer. There is full documentary proof, however, of the presence of smalt in the priming layers from Velázquez's second stage in Madrid. In Andalusia, and specifically in Seville, they are often identified in paintings by artists who were active at some time throughout the entire century: we have been able to observe them in priming layers on paintings by Francisco de Zurbarán, Juan de las Roelas, Francisco Herrera el Viejo, Juan de Valdés Leal and Sebastián de Llanos y Valdés.

¹ Boon, J.J., Keune, K., Van der Weerd, J., Geldof, M., and Van Asperen de Boer, J.R.J., 'Imaging microspectroscopic, secondary ion mass spectrometric and electron microscopic studies on discoloured and partially discoloured smalt in cross-sections of 16th century paintings', *Chimia* 55 (2001) 952-960.

² Hand, J.O., and Mansfield, S.E., *The Collections of the National Gallery of Art Systematic Catalogue. German Paintings of the Fifteenth through Seventeenth Centuries*, National Gallery of Art (1993) 84.

³ Strolz, M., 'Zu Maltechnik und Restaurierung des Porträts der Jane Seymour von Hans Holbein d.J.' *Technologische Studien: Kunsthistorische Museum* 1 (2004) 8-31, particularly 14-16.

⁴ Foister, S., Wyld, M., and Roy, A., 'A Lady with a Squirrel and a Starling', *National Gallery Technical Bulletin* 15 (1994) 9.

A surprising ground layer in Rembrandt's portrait of *Nicolaes van Bambeek*

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The portrait of Nicolaes van Bambeek (Royal Museums of Fine Arts of Belgium, Brussels), painted by Rembrandt van Rijn in 1641, was restored at the Royal Institute for Cultural Heritage (KIK/IRPA). During this restoration the painting technique of Rembrandt was further studied. The most striking result was the revelation of a peculiar composition of the second greyish ground layer. In this layer a fairly high concentration of starch mixed with lead white, to which small amounts of carbon black and red lead have been added, was found. The starch was unambiguously identified using micro-Raman microscopy and visualized on a cross-section after staining with a KI/I₂ mixture. The presence of starch in ground layers of Rembrandt's paintings has never been reported.¹ The ground layers were further characterized using different analytical techniques such as GC-MS, FTIR, HPLC-MS, MALDI-ToF-MS and SEM-EDX.

The results of this study were compared with those from other grounds of Rembrandt paintings obtained during the Rembrandt Research Project at The Netherlands Institute for Cultural Heritage (ICN).

¹ Groen, C.M., 'Grounds in Rembrandt's workshop and in paintings by his contemporaries' in *A Corpus of Rembrandt paintings*, ed. E. van de Wetering, Dordrecht, Vol. IV (2005) chapter 4, 318-334.

Combing, texturing and other hidden effects in paintings of the sixteenth and seventeenth century: Purpose and perception

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The microscopic examination of a sixteenth-century painting by Pourbus – *The Allegory of Love* (Wallace Collection) – revealed a technique of paint manipulation or handling not previously noted by the author or by the conservator, Anna Sanden on any other work. The paint surface of many parts of the picture (though not all) had been systematically ‘combed’ with an unknown tool, forming a myriad of parallel lines in the oil paint on a microscopic scale: these lines were not visible to the naked eye. This finding raised important questions. What was the purpose of this texturing technique? Was it related to the practicality of paint application, did it speed the drying, or did it attempt to achieve a certain aesthetic or meaning within the composition? Was it unique to Pourbus, or more widespread?

Examination and analysis of numerous sixteenth- and early seventeenth-century paintings, as part of a large project at the National Portrait Gallery, *Making Art in Tudor Britain*, has provided a significant opportunity to research this question, producing further finds. Smaller, perhaps similar serrated tools, producing regularly spaced lines in the paint, appear to have been employed on particular features of portraits: items such as hair, fur, eyelashes seem to have been depicted by applying or sculpting the paint with some sort of small-scale combing instrument. A more visible vertical ‘combing’ has been observed in the background paint of some sixteenth-century portraits, where the pigment smalt has been employed. This finding poses the question of whether the technique is simply a manner of handling awkward pigment such as ‘strewing blue’, or whether, like the Pourbus technique, it might also produce a desired aesthetic effect, or refer to the personal qualities or symbols of the sitter.

The use of palms, fingers, cloth etc. to soften, mute, smooth, or pattern paint have frequently been noted on paintings of this period (as they have in all periods) but other texturing techniques are beginning to show themselves through routine surface examinations of paintings under the stereo microscope. As with the combing technique, it is not always easy to know what means or material was used and the exact effect intended.

The present research explores these and other examples of painters’ hidden or unnoticed handling of paint; techniques which probably recognise the principle in the viewer of perception without awareness. Based on a study of sixteenth- and seventeenth-century painters, such techniques may be an extension of earlier explorations of the oil medium, when painters were learning to manage oil, and when they were likely to keep both the methods and the tools employed a secret within the workshop. Analysis, reconstruction of the techniques and documentary evidence are being used to investigate these techniques and provide a basis for exploring artists’ intentions in using them.

Re-defining Hendrick Avercamp: A study of the artist's painting technique

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Hendrick Avercamp (Amsterdam 1585-Kampen 1634) is best known for his vivid and story telling winter landscapes. His *Winter landscape with ice skaters* (oil on panel 77 x 132, RMA inv. nr. sk-a-1718) is generally considered to be one of the major masterpieces of the Rijksmuseum. Although Hendrick's work has always been appreciated, for a long time little was known about the artist's life and career. This changed with the monograph on Avercamp by Welcker, first published in 1933.¹ An important fact revealed by Welcker was the date of Avercamp's death in 1634. She concluded that works which had previously been attributed to Avercamp, but originated after his death, must therefore have been made by his nephew Barend Avercamp (Kampen 1612/13- Kampen 1679). Not only paintings by Barend firmly resemble the work of Hendrick, also works by artists such as Arent Arentsz and Adam van Breen are very similar to Hendrick's, making it difficult to define the artist's oeuvre.

In preparation for the upcoming Rijksmuseum Amsterdam exhibition *Hendrick Avercamp: The little Ice Age*, research was undertaken to gain insight into Avercamp's painting technique. In this study paintings as well as sketches, drawings and watercolours on paper by the artist and artists surrounding him, in the collection of the Rijksmuseum Amsterdam are examined as well as several works in collections in the Netherlands and abroad. Infrared reflectography, X-radiography, the examination of paint cross-sections, and dendrochronological research, were used in this study to gain an in-depth understanding of Hendrick Avercamp's working processes.

Remarkable features of Hendrick's work have been found, that appear to be distinctive of the artist. On top of the artist's conventional chalk ground for instance, an overall irregular paint mixture containing large amounts of smalt, lead white and some carbon black were found. This often thick and unusual paint layer appears to be applied on top of the artist's sketchy and typical underdrawing and most likely explains the blotchy appearance of the X-radiographs of Hendrick's paintings. Did the artist apply the smalt-containing layers because of their almost glassy appearance to conceive his distinct greyish blue, icy winter atmospheres? Some of Hendrick Avercamp's underdrawing is visible to the naked eye, especially where it differs from the final paint layers and shows through this smalt-containing layer, which is left exposed in large parts of the final paint surfaces. This

¹ Welcker, C.J., *Hendrick Avercamp 1585-1634 bijgenaamd 'De stomme van Campen' en Barent Avercamp 1612-1679, 'schilders tot Campen'*, Uitgave der Vereeniging tot beoefening van Overijsselsch regt en geschiedenis ter gelegenheid van 75-jarig bestaan 1858-1933, Zwolle (1933).

is especially visible in the trees, giving them the realistic appearance of branches disappearing in cold grey winter skies. One could argue that this effect was intended by the artist, though this could also be attributed to changes made by the artist which have become visible over time. To answer these questions, a reconstruction of Avercamp's methods and techniques was made following the obtained technical data. This technical study may be used as a tool in the re-defining of the artist's oeuvre and its chronology.

ADDITIONAL PAPERS

Included for publication in the postprints
(not presented)

Wood species in Italian panel paintings (fifteenth to sixteenth centuries): Historical investigation and microscopical wood identification

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Although Italian written sources (Cennino, Alberti, Leonardo, Baldinucci) stated the use of several wood species in panel paintings,¹ Italian artists are generally cited as using poplar (*Populus sp.*). This assertion needs to be supported with evidence as there are various exceptions to this general rule. In fact, according to Jacqueline Marette's pioneering *Connaissance des primitifs par l'étude du bois* (1961),² we can assume the predominance of poplar panels, but also the presence of many other species including both gymnosperms (*softwoods*) and angiosperms (*hardwoods*). However, only Peter Klein's recent works demonstrate that in many cases microscopic and not macroscopic wood identification must be carried out, particularly when distinguishing between poplar (*Populus sp.*) and lime (*Tilia sp.*) because they seem similar and can only be identified through microscopic analysis.³ In contrast with Flemish painters, who used only oak and imported oak boards expressly from the Baltic regions, Italian painters seem to use local wood species. This is shown in a 1486 document which mentions that the son of the Genoese painter Giovanni Mazzone used to go to a local forest called *La Pria* to choose the wood for panel paintings. The aim of our paper is to present the results of research which focuses on the wood species in Italian panel paintings from the fifteenth and sixteenth centuries. After discussing the Italian written sources, we will present data from both recent literature and the analysis of samples. More than 45 museum and exhibition catalogues have been examined, recording 429 types of wood used in Italian panel paintings.⁴ Out of 429 panels, 340 are poplar but 89 are many other species, including walnut (*Juglans regia* L.) in Lombardy, and spruce (*Picea abies* Karst.) and lime (*Tilia sp.*) in Veneto.

¹ Cennini, C., *Il libro dell'arte*, early 14th century, edited by R. Frezzato, Vicenza (2003) 142.

Alberti, L.B., *L'architettura*, edited by C. Bartoli, Venezia (1565), anastatic reprint, Bologna (1984) 44-47.

Da Vinci, L., *Scritti scelti*, edited by A.M. Brizio, Torino (1952) 181, 678, 679.

Baldinucci, F., *Vocabolario toscano dell'arte del disegno*, Firenze (1681) 1-168.

² Marette, J., *Connaissance des primitifs par l'étude du bois*, Paris (1961) 10-384.

³ Klein, P., and Bauch, J., 'Analyses of Wood from Italian Paintings with Special Reference to Raphael', in *The Princeton Raphael Symposium. Science in the Service of Art History*, ed. J. Shearman and M.B. Hall, Princeton (1990) 85-91.

⁴ *Carpaccio, Bellini, Tura, Antonello e altri restauri quattrocenteschi della Pinacoteca del Museo Correr*, ed. A. Dorigato, Milano (1993).

Boskovits, M., Alan Brown, D., *Italian paintings of the Fifteenth Century. The Collections of the National Gallery of Art. Systematic catalogue*, Washington (2003).

Gordon, D., *NG Catalogues. The 15th Century Italian paintings*, London (2003).

Penny, N., *NG Catalogues. The 16th Century Italian paintings*, London (2003).

Hiller Von Gaertringen, R., *Italienische Gemälde in Städel 1300-1550. Toskana und Umbrien*, Frankfurt am Main (2004).

Sander, J., *Italienische Gemälde im Städel 1300-1550. Oberitalien, die Marken und Rom*, Frankfurt am Main (2004).

The second part of the paper consists of an experiment in which 24 wood samples (a few millimetres wide) were taken from fifteenth- and sixteenth-century panel paintings of different Italian schools housed in the *Pinacoteca Malaspina*, Pavia. Wood identification was carried out using a microscope in the Wood Biology Department (Hamburg University) and in WSL (Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf).⁵ Chemical and morphological information was obtained through FTIR and SEM analyses at CBA (Advanced Biotechnology Centre), Genoa. Out of 24 samples, 19 are poplar (*Populus sp.*), 2 are spruce (*Picea abies* Karst.), 1 is walnut (*Juglans regia* L.), 1 is fir (*Abies alba* Mill.) and 1 is unidentified (but is certainly not poplar). These results confirm the hypothesis of the presence and use of different kinds of wood in different Italian regions, in particular spruce in Veneto and North-Eastern Italy and walnut in Lombardy.

Studying the 'Graue Passion' of Hans Holbein the Elder

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In 2002 the Staatsgalerie Stuttgart was able to acquire the 'Graue Passion' of Hans Holbein the Elder.

The cycle is part of an altarpiece created presumably around 1495 and shows the Passion of Christ in twelve scenes. Nowadays, neither the exact place of origin nor the construction of the altar is known, but it can be assumed that the twelve wooden panels formed the front and back of two wings. Known for his psychological interest in the portrayal of his characters, the expression Holbein gave to central figures of the scenes is, even today, both astonishing and gripping. Moreover, the 'Graue Passion' provides another attraction in the unique use of colour by the artist: Holbein mainly worked with a reduced palette of 'grau' (i.e. German for the English word 'grey') and ochre tones connected to the 'Grisaille'-painting of the time and giving name to the cycle today.

The conservation and restoration of the panels due to an exhibition in 2010 offers the opportunity for a thorough investigation by painting conservators, scientists and art historians. Besides recording the condition of the artwork with detailed and extensive digital documentation, and reconstructing the restoration history, the attention is directed towards the technical study and the comprehension of the artist's working process.

The great possibility to compare the twelve panels to each other allows some general comments on the execution and working habits of the artist and his workshop. It is possible for the first time to study the 'Graue Passion' and the technique of Holbein the Elder and his personnel on such a large scale.

Examining the cycle from scratch, the underdrawing is the subject of discussion after the construction of the panels and the preparation of the ground. Infrared reflectography suggests different kinds of drawing 'styles' and media used in underdrawing, which can be related to various states of execution. Besides a very detailed and artistic drawing with hatches in shaded areas using quill, brush and a wet medium, a sort of raw composition of single hard lines from a dry medium is visible in some places. In this context the issue of the use of masters is addressed and focus is laid on the generation of the drawing on the panel especially in connection with other paintings by Holbein the Elder.

The survey of the paint and varnish layers focuses on the sequence of layers and their ingredients. As the cycle endured several conservation and restoration treatments in the past the question of authenticity of the material is addressed in this context as well.

⁵ Schweingruber, F.H., *Mikroskopische Holz Anatomie*, Birmensdorf (1978).

The study is supplemented with an extensive scientific examination including analysis of paint samples and binding medium to receive significant information about the materials used.

Finally, the attempt is made to regard Holbein's painting technique in the context of the materials and practices at the turn of the Renaissance in northern Europe.

In search of the right colour. Colour notations on a late sixteenth-century Dutch painting

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Recent investigations with IRR on a little known painting in the Museum Boijmans Van Beuningen in Rotterdam have shown a remarkable and very extensive use of colour notations. The painting in question, which represents the *Seven Acts of Mercy*, was made by an anonymous artist and is dated 1580. It is signed with a mark, which till now has not been identified. Thanks to the date and the coat of arms depicted in one of the windows the *Seven Acts of Mercy* can be situated in Haarlem. The panel was probably commissioned by inhabitants of the beguinage of that city, its church being visible in the background. Stylistically it is related to the work of Pieter Pietersz, an artist active in Amsterdam and Haarlem in this period.

Until now, colour notations have been discovered in many paintings from different language areas. These include works from the Northern Netherlands, such as the interesting examples in Lucas van Leyden's *Dance around the golden calf* (Amsterdam, Rijksmuseum).¹ In this triptych references both to colours as well as to specific pigments are present. However, in most cases the notations consist of a few letters or at most the entire word referring only to the colour to be applied, as in paintings by Pieter Pietersz.²

Dated 1580, the *Seven Acts of Mercy* is one of the latest paintings in which colour notations have been discovered so far. They consist not only of references for plain colours, but also for the pigments to be used. Rarely seen in Northern Netherlandish paintings, however, is a notation for the type of material to be painted. A reference to the way in which the paint should be applied is so far unprecedented. Equally striking is the active search for the appropriate colour. On several occasions a notation has been written, then struck out, and replaced by another. Of particular interest is an example of a notation which gives a choice between two colours, one of which is preceded by what might be a surname, perhaps of the person who provided the pigment. Different handwritings suggest that more than one person was involved in the process of applying the colour notations. Sometimes the notation was not followed and a completely different colour used.

Cross-sections and paint sample analyses offer insight into the way in which these written indications functioned as a guideline while the paint layers were being applied. Furthermore it makes clear that some of the colours of the notated pigment, for example 'lack' (lake) now appear in the painting in several completely different hues and that other colours must have discoloured over time.

¹ Filedt Kok, J.P., *De Dans om het gouden kalf van Lucas van Leyden*, Amsterdam (2008) 44-45.

² Van den Brink, P., 'Het Petrus en Paulus altaarstuk van Pieter Pietersz in Gouda. Verslag van een natuurwetenschappelijk onderzoek', in: *Nederlands Kunsthistorisch Jaarboek 40 (1989) Pieter Aertsen*, Den Haag (1990) 235-262, 245-247.

Venice White: Archival and technical evidence for high quality lead white

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Venice was well known as a center for the manufacture of lead white pigment, and several other corrosive substances used as pigments, from the late Middle Ages until the seventeenth century. Archival documents, especially shop inventories, are beginning to provide us with a more specific picture of how lead white, one of the earliest manufactured pigments and the only white pigment widely used by artists until the nineteenth century, was produced in Venice. The material made there was highly regarded, so much so that by the sixteenth century the city lent its name to the pigment, denoting its high quality. The inventories indicate the large scale of production through the Dutch process. The specialized tools, containers, and materials listed in the inventories indicate that the material produced could be highly worked-up. The tools included pots for washing, as well as implements for grinding, and forming the pigment into shapes such as cakes and loaves. Work-up of the product appears to have been extensive, based on the number of copper basins for washing the raw material. It is perhaps this washing or rinsing that gave rise to a product of great purity. Washing also provided a product with specific particle size. It is known that the texture, stiffness, and thixotropic properties of paint are influenced by particle size distribution.¹ We will be determining this distribution in samples from Venetian paintings.

X-ray diffraction of paint films show that there was variation in the proportion of neutral to basic lead carbonate, even within one painting. One example: In the *Feast of the Gods*, the priming was prepared from a product that contained about equal proportions of normal and basic cerussite, while that used for the pictorial layers is entirely hydrocerussite. In contrast, the paint layers in Dosso Dossi's *Circe* is similar to the priming in Bellini's work. Other documents shed light on the extensive commerce – wholesale and international even more than retail and local – that spread the Venetian product far and wide, enhancing its reputation and making the lead white manufacturers quite rich. We are collecting information on prices for lead white, and the variety of shapes and weights in which it was shipped. This talk will combine a consideration of these documents with the scientific analysis of lead white in paintings, examining how Venetian lead white was manufactured and sold and how it was used by painters (and other artisans). The re-examination of lead white paints, which at first glance seem homogeneous and unworthy of investigation, is expanding our understanding of the pigment trade in Venice. We hope that it may also deepen our understanding of the techniques and aesthetic choices that underlay the making of pictures in Renaissance Venice.

¹ Groen, K., 'Investigation of the Use of the Binding Medium by Rembrandt: Chemical Analysis and Rheology', *Zeitschrift für Kunsttechnologie und Konservierung* 11(2) (1997) 207-227.

'...verguldet oder versilbret und glasiert...' – techniques and artists' materials of coloured glazes on metal leaf in Germany, Austria and Switzerland (c.1500-1800)

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Polychrome works of art (e.g. sculptures, altarpieces, architecture) from all periods and places are an important part of our cultural heritage and in many cases are still worshipped, admired or studied in the places they were originally intended for, such as churches, monasteries, palaces and castles. Artists who were responsible for the polychrome or multi-coloured design of these surfaces were often trained painters who also created easel and mural paintings. It is documented that some of the most significant Northern European artists of the fifteenth and sixteenth centuries occasionally polychromed sculptures, including: Michael Pacher, Hans Burgkmair, Bernt Notke, Veit Stoss, Rogier van der Weyden, Jan van Eyck and Robert Campin. Combining this evidence with the numerous scientific examination results obtained so far, it can be concluded that polychroming techniques are comparable to those found on paintings with equally sophisticated and complex layer build-ups. This is especially evident with coloured glazes on metal leaf, which are found on a great number of artworks in Germany, Austria and Switzerland going back as far as the twelfth century. Their use is documented in numerous contracts dating from the fifteenth to eighteenth centuries. One good example is a contract from 1518, which instructs the painter Hans Herbst to paint a landscape for an altarpiece for the cloister church of St. Mary Magdalene in Basel using coloured glazes on gold or silver leaf (*...die landschaft in der tafel verguldet oder versilbret und glasiert...*).

Coloured glazes on metal leaf surfaces have been widely used by artists to embellish works of art to give them meaning and optical dynamism. Special luminous colours (mainly red, green and blue) are created by the reflection of the light transmitted through the glaze from the metallic surface underneath. These delicate and refined coatings are frequently found on paintings and polychrome sculpture, but are also commonly encountered on other works of art (e.g. illuminated manuscripts, architectural polychromy, gilt leather, furniture). In fifteenth- and sixteenth-century painting and polychromy they were often used to imitate precious stones as well as costly techniques such as goldsmiths' art, enamel or textiles. In the seventeenth and eighteenth centuries the uses of coloured glazes in German-speaking countries reached new heights and were applied on a much larger scale especially in connection with the imitation of precious materials (e.g. lapis lazuli, enamel, tortoiseshell, textiles). Often this technique – which is actually a combination of techniques – revealed an unforeseen complexity due to the multi-layered build-up and the use of

various material mixtures, including a broad spectrum of colourants, binding media, metals, additives as well as fillers. The case studies presented in this paper will not only demonstrate the multi-faceted character of coloured glazes from a material point of view but will also show the high level of artistic skill and technical knowledge required to produce such refined luxury effects.

Lead white terminology in North West European written sources from the fifteenth to the nineteenth century

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The frequent use of basic lead carbonate (lead white) in paintings has led to attention in written sources from Antiquity onward. Its properties have been described in different languages and at different moments in time, however the composition and quality of different grades of lead white is not always certain.

This paper investigates different lead white production methods, lead white names and their respective qualities as presented in written sources from the fifteenth to the nineteenth century. It draws its information from a large body of recipes of lead white (c. 560 entries) and its use in ground layers (c. 600 entries).¹ The large number of recipes and their division over time provide a unique opportunity to investigate in detail the issues raised above.²

Recipes confirm that, especially after the introduction of new production methods during the eighteenth and nineteenth century, a multitude of lead whites were available, whose quality apparently differed considerably. According to the sources, lead white quality depended on the raw materials, the method of production, the material's subsequent purification and the presence of adulterants in the finished product.

An artist looking for high quality lead white had to face many challenges. The adulteration of lead white with fillers such as chalk or barium sulphate resulted in advice to buy lead white in flakes ('flake white'), not ground to a powder. However, even flake white was not always what it seemed since (according to Weber, 1781) adulterated lead white could be made to look just like flake white by the addition of starch.³

Nomenclature for different lead white qualities changed throughout the centuries. Seventeenth-century Dutch stack-process lead white was known for its high quality and its production process was adapted by other countries, whereas several nineteenth-century sources explain that the material available by that time as Dutch lead white was a low grade lead white with additions of up to 75% of fillers.

¹ Recipes were gathered by the author and by Dr. Leslie Carlyle as part of the De Mayerne Project. (Witlox, M., and Carlyle, L., "A perfect ground is the very soul of the art" (Kingston 1835): ground recipes for oil painting, 1600-1900', in *ICOM Committee for Conservation, 15th Triennial Meeting, The Hague, 2005: Preprints*, James & James, London (2005) vol. I 519-528.) and as part of the ongoing PhD research of the author, titled 'Historical recipes for preparatory layers for oil painting in North West European sources, 1400-1900', University of Amsterdam.

² Although several of the above aspects have been partially described by various authors (e.g. Gettens, Stout, Kühn, Harley), the subject has not been dealt with as concisely and systematic as possible at present.

³ Weber, J.U., *Bekante und Unbekante Fabriken und Künste*, Tübingen, Jakob Friedrich Heerbrandt (1781)

Exact knowledge of contemporary lead white terminology is important for the correct interpretation of historical recipes for painting methods and materials. It allows for a better understanding of analytical results and may shed light on whether certain pigment mixtures were prepared commercially or by artists themselves, such as mixtures of lead white and Berlin blue, indigo or soot, which (according to Leuchs, 1825) were available commercially as 'pearl white', designed specifically to remove the yellow tinge present in pure lead white.⁴

Furthermore, lead white quality has implications for the ageing characteristics of paint layers and may influence phenomena such as lead soap formation, the resulting increase in transparency and possible formation of lead soap protrusions.

Developments in the underdrawing and painting technique of the sixteenth-century Leiden School, in particular the workshops of Cornelis Engelbrechtsz and Lucas van Leyden

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In the first half of the sixteenth century, the workshop of Cornelis Engelbrechtsz (c.1462-1527) was very influential in the development of painting in Leiden, the Netherlands. Two of his major triptychs – the *Lamentation* (c.1508) and the *Crucifixion* (c.1515-18) – were mentioned in Karel van Mander's *Schilder-boeck* (1604).¹ Recently, the *Lamentation* underwent an extensive conservation treatment, during which it was examined with microscopy, infrared reflectography (IRR) and X-radiography. Paint samples were taken and analysed with polarized light microscopy (PLM), microchemical analyses (MCA), micro X-ray fluorescence (μ -XRF), X-ray diffraction (XRD), high performance liquid chromatography (HPLC), and light- and electron microscopy (LM + SEM-EDX). The results of this study formed the basis for the examination of other paintings by Engelbrechtsz, including the *Crucifixion* triptych. The new investigation focused on non-destructive methods, such as IRR and microscopic examination of the painted surface. Developments in the working methods within the workshop of Engelbrechtsz are demonstrated by comparing the underdrawing and painting techniques, especially in the draperies and brocades.

One of Engelbrechtsz's best-known pupils is Lucas van Leyden (1494-1533). Two of his documented altarpieces were also examined: the *Last Judgment* (c.1526-27) and the *Dance Around the Golden Calf* (c.1530).² The *Last Judgment* was extensively researched in the early 1970s, in combination with a conservation treatment. Now, thirty years later, new IRR images and re-examination of the existing paint samples have been combined with an investigation of the *Dance Around the Golden Calf*. This shed new light on the working methods of Lucas van Leyden.

⁴ Leuchs, J. C., *Anleitung zur Bereitung aller Farben und Farbflüssigkeiten*, ..., no publisher, Nürnberg, (1825)

¹ van Mander, K., *The Lives of the Illustrious Netherlandish and German Painters, from the first edition of the 'Schilder-boeck' (1603-1604)*, ed. H. Miedema, Doornspijk (1994) fol. 210v. Both altarpieces are now in the collection of the *Stedelijk Museum de Lakenhal* in Leiden.

² van Mander, K., *The Lives of the Illustrious Netherlandish and German Painters, from the first edition of the 'Schilder-boeck' (1603-1604)*, ed. H. Miedema, Doornspijk (1994) fol. 213v. The *Last Judgment* belongs to the Lakenhal, the *Dance Around the Golden Calf* is owned by the Rijksmuseum, Amsterdam.

Comparisons between the technique of master and pupil explain the development from the meticulously prepared and intricate compositions by Engelbrechtsz into Lucas van Leyden's sketchier and less detailed manner of working. The investigation into works by other Leiden School painters puts the influence of these two artists into a larger context.

The current research is being conducted as part of the *Impact of Oil* project: a history of oil painting in the Low Countries and its consequences for the visual arts, 1350-1550.

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